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Research article

Nutritional and pharmacological potentials of orphan legumes: Subfamily faboideae

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A R T I C L E I N F O

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A B S T R A C T

Legumes are a major food crop in many developing nations. However, orphan or underutilized legumes are domesticated legumes that have valuable properties but are less significant than main legumes due to use and supply restrictions. Compared to other major legumes, they are better suited to harsh soil and climate conditions, and their great tolerance to abiotic environmental circumstances like drought can help to lessen the strains brought on by climate change. Despite this, their economic significance in international markets is relatively minimal. This article is aimed at carrying out a comprehensive review of the nutritional and pharmacological benefits of orphan legumes from eight genera in the sub-family Faboidea, namely *Psophocarpus* Neck. ex DC., *Tylosema* (Schweinf.) Torre Hillc., *Vigna* Savi., *Vicia* L., *Baphia* Afzel. ex G. Lodd., *Mucuna* Adans, *Indigofera* L. and *Macrotyloma* (Wight & Arn.) Verdc, and the phytoconstituents that have been isolated and characterized from these plants. A literature search was conducted using PubMed, Google Scholar, and Science Direct for articles that have previously reported the relevance of underutilized legumes. The International Union for Conservation of Nature (IUCN) red list of threatened species was also conducted for the status of the species. References were scrutinized and citation searches were performed on the study. The review showed that many underutilized legumes have a lot of untapped potential in terms of their nutritional and pharmacological activities. The phytoconstituents from plants in the subfamily Faboideae could serve as lead compounds for drug discovery for the treatment of a variety of disorders, indicating the need to explore these plant species.

1. Introduction

The Food and Agriculture Organization (FAO) described orphan, underutilized or neglected crops as species that have lost relevance over the last 500 years due to societal, agronomic, or biological factors [1]. The original function or likely usage of some of these crops has been downplayed over time, whereas others have essentially been forgotten. Orphan or underutilized crops have played a substantial role in indigenous peoples' and communities' agriculture and food supply but have not been economically exploited globally, and thus have received little attention from research networks [2]. In many instances, their neglect resulted in the deliberate

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suppression of self-sufficient lifestyles modelled by older generations [1].

Legumes have been cultivated for several years virtually in every part of the world and have been a vital ingredient in the human diet. Due to their capacity to fix atmospheric nitrogen symbiotically, they are also acknowledged as the most valuable contributor to world food production and nutrition [3]. Most grain legumes are cultivated particularly, for human consumption as pulses, whereas pasture legumes are grown for the production of livestock feed. Grain legumes have high nutritive qualities such as remarkably high protein content which have vital effects on the well-being of humans around the globe [4]. From large rainforest trees to small herbs and shrubs, Africa contains a diverse range of indigenous legumes. Although indigenous people in Africa have used nodulated legumes for generations, their full potential has never been realized. However, recently, there has been a trend in forestry and agriculture to utilize exotic plant species thereby ignoring the potential of the indigenous native species that are no doubt more adapted to their environment [5].

It has become clear that a lack of variety in the human diet caused by focusing on very few crops can have negative implications on the health of humans, including malnutrition and diseases linked to diet. On the other hand, underutilized crops have a high nutrient content and other health-promoting ingredients that aid the prevention of malnutrition and some chronic diseases. They also offer a lot of potential for enhancing local community nutrition. Therefore, adding these underutilized plant species to the food chain might be a useful technique for improving human health and nutrition [6]. In addition to their nutrient content, African legumes also contain non-nutritive phytochemical constituents that are beneficial to health. These include phytochemicals such as phenolics, which may contribute to their health-promoting benefits, especially in diet-related non-communicable diseases [7].

Legumes belong to the Family Leguminosae, which is the third-largest plant family with about 765 genera and over 19,500 species [8]. The Leguminosae family has traditionally been divided into three notable and globally accepted subfamilies, Caesalpinioideae DC., Mimosoideae DC., and Faboideae DC [8]. However, this categorization does not effectively describe evolutionary relationships within the family [9,10]. Thus, the new classification of Leguminosae, based on a phylogenetic structure, which represents a consensus view of the international legume systematics community recognises six subfamilies in Leguminosae: Caesalpinioideae DC., Cercidoideae LPWG, Detarioideae Burmeist., Dialioideae LPWG, Duparquetioideae LPWG, and Faboideae DC. (Papilionoideae DC.) [11]. A diagram of the phylogenic classification of the family Leguminosae is shown in Fig. 1.

The subfamily Faboideae, also known as Papilionoideae, is the largest group of legumes containing 503 genera and approximately 14,000 species [11]. Members of the Faboideae subfamily, like those of the other subfamilies, originated from the tropics, but are widely spread throughout the world's desert and temperate regions, usually as trees, shrubs or herbaceous plants. They are among the most prevalent plants in forests, savannahs, and deserts. The pea-shaped flowers resembling a butterfly are a distinguishing characteristic of the group. Many Faboideae plants have nodules in their roots that contain the nitrogen-fixing bacterium Rhizobium [12]. Some major legumes in the subfamily Faboideae that are commonly cultivated and domesticated include *Glycine* max (soybean), *Arachis hypogaea* L. (groundnut), *Pisum sativum* L. (pea) and a host of others. However, several of the legumes from the subfamily such as *Psophocarpus tetragonolobus* L., *Vicia faba, Vigna mungo* L., *Vigna umbelleta* (Thunb.) Ohwi & H. Ohashi, *Canavalia* sp., *Cajanus cajan* L., *Phaseolus lunatus* L., etc. have been neglected, less cultivated and regarded as underutilized, even though they grow widely in the tropics [4]. The ability to harness the potentials derivable from these legumes could contribute toward alleviating the food and hunger challenges by ensuring food availability and nutrient security in tropical Africa. Moreover, information about the underutilized legumes from this subfamily is scattered despite increasing interest in their potential benefits. There is a need to gather available scientific evidence that could support their utilization and applications. Thus, this paper presents a review of species of underutilized legumes commonly found in the tropics from eight genera of the subfamily Faboideae, to determine their relative usefulness either as food or a source of phytochemicals which could be useful for the treatment of diseases.

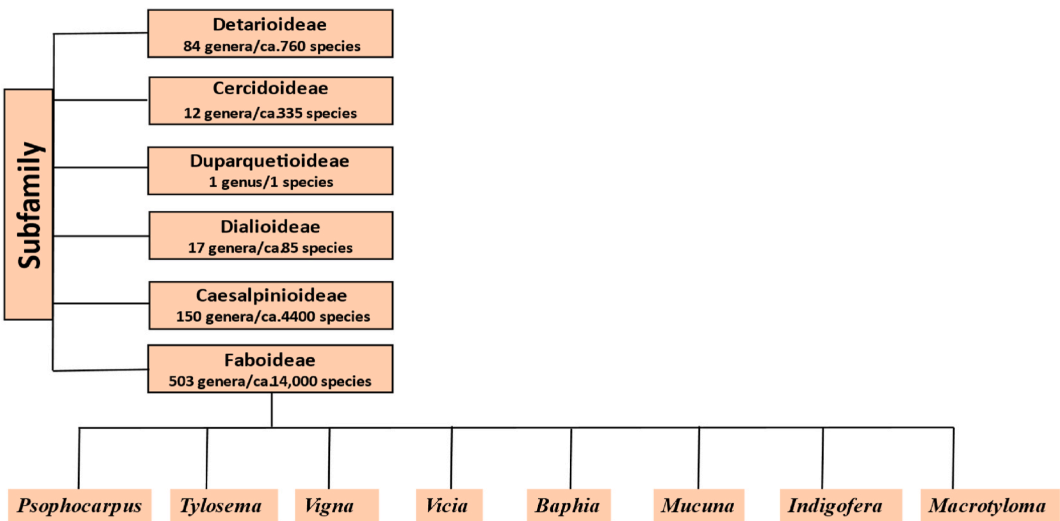

Fig. 1. Diagram of the phylogenic classification of the family Leguminosae.

2. Methodology

A comprehensive literature search was conducted using PubMed, Google Scholar, and Science Direct, for articles that have previously reported the nutritional and pharmacological properties of the underutilized legumes from the subfamily Faboideae. The keywords used were legumes, underutilized legumes, orphan legumes, nutritional value, and medicinal properties. About 21,800 articles obtained were further analyzed and the most relevant articles reporting the nutritional and pharmacological properties of the orphan legumes were selected. The references were scrutinized, and citation searches were performed. The International Union for Conservation of Nature (IUCN) red list of threatened species was also consulted for the status of the species. The schematic diagram of the methodology adopted is presented in Fig. 2.

3. Results

There are several studies on the nutritional and pharmacological properties of underutilized legumes. We were able to identify species from eight genera in the sub-family Faboideae (Fig. 1), namely *Psophocarpus* Neck. ex DC., *Tylosema* (Schweinf.) Torre Hillc., *Vigna* Savi., *Vicia* L., *Baphia* Afzel. ex G. Lodd., *Mucuna* Adans, *Indigofera* L. and *Macrotyloma* (Wight & Arn.) Verdc, that have been researched for evidence to support their nutritional potentials and folkloric use. A summary of the species, the pharmacological properties and the isolated compounds are presented in Table 1.

3.1. *Psophocarpus Neck. ex DC*

This is a genus that belongs to the legume family, Fabaceae. Nine species that have been identified are *Psophocarpus grandiflorus* R. Wilczek, P. *lancifolius* Harms, *P. lecomtei* Tisser., *P. lukafuensis* (De Wild.) R. Wilczek, *P. monophyllus* Harms, *P. obovalis* Tisser., *P. palustris* Desv., *P. scandens* (Endl.) Verdc. and *P. tetragonolobus* (L.) DC. Eight of these are native to tropical Africa, while the ninth species is the economically available winged bean, *P. tetragonolobus* (L.) DC., which is native to Asia and has been introduced as a crop to other tropical areas [75,76]. Various organs of three of the species, *P. scandens, P. grandiflorus*, and *P. Lancifolius* are used as food and medicine while *P. Lecomtei* has been reported to be used as fish poison in some parts of Africa [77]. Most of the studies conducted on the *Psophocarpus* species have been on the commercially important *P. tetragonolobus*.

3.1.1. *Psophocarpus tetragonolobus (L.) DC*

Psophocarpus tetragonolobus also known as *Lotus tetragonolobus*, Asparagus bean, Asparagus pea, *Dara-Kambala*, Goa bean, Princess bean, Wing bean or Winged bean is a tropical leguminous plant commonly called "poor man's food" since all the plant parts are consumed raw or cooked. Owing to its exceptionally high protein content, it is referred to as the "tropical soybean" and has been proposed as a promising source of food for the tropics [78]. The tubers of winged beans can be cooked, steamed, baked, fried, roasted, and even made into chips. Aside from being edible, the fruits have anti-inflammatory, antioxidant, and anti-nociceptive properties.

P. tetragonolobus has a high nutrient composition with the starchy tubers containing 17–20% (by weight) protein, the leaves and flowers containing 5–15% while the seeds contain 32–37% protein, which is comparable to the proteins content of soybeans [13].

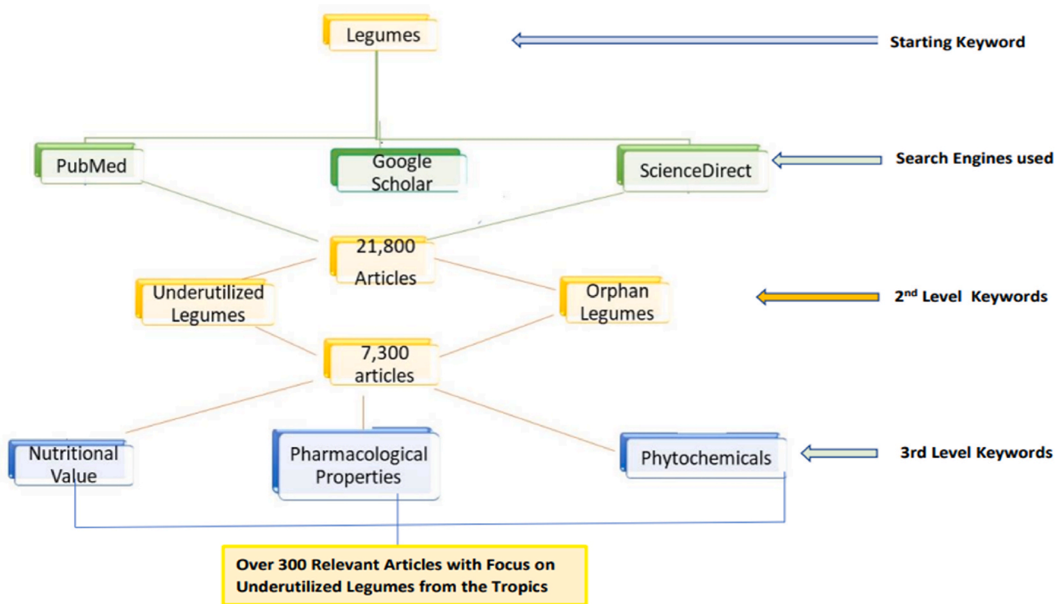

Fig. 2. A schematic diagram of the methodology.

Table 1
Pharmacological uses of the reviewed plants and their phytochemical compounds.

S/N	Genus	Species	Pharmacological use	Phytochemical compound	Reference
1	***Psophocarpus* Neck. ex DC**	***Psophocarpus tetragonolobus***	Anti-inflammatory, antioxidant, antifungal, anti-nociceptive and antiproliferative	Gallic acid, quercetin, phytate, phaseolin	[13,14,15]
2	***Tylosema* (Schweinf.) Torre Hillc.**	***Tylosema fassoglense***	Antidiarrheal, antibacterial and antimicrobial	Proathocyanidin, syringic acid and 4-hydroxybenzoic acid	[16,17]
		Tylosema esculentum	Antioxidant, antibacterial and anticandidal	Gallic acid, epicatechin-3-O-gallate, epigallocatechin, epigallocatechin-3-O-gallate and epicatechin	[18,19,20,21]
3	***Vigna* Savi.**	***Vigna unguiculata***	Antisickling, antioxidant, antifungal, antibacterial, hypolipidemic, antidiabetic and anti-atherogenic	*p*-hydroxybenzoic acid, *p*-coumaric acid, catechin and dihydroxybenzoic acid	[22,23,24,25–27]
		Vigna subterranea	Hypoglycemic, antioxidant, hypolipidemic, hepatoprotective, anti-inflammatory and anti-tumour	Myricetin, rutin, quercetin, kaempferol, gallic acid, catechin, methyl gallate, chlorogenic acid and ellagic acid	[28,29,30]
		Vigna vexillata	Anti-inflammatory and antioxidant	Daidzein, abscisic acid, and quercetin	[31,32]
4	***Vicia* L.**	***Vicia faba***	Antioxidant, anti-inflammatory, antifungal and antimicrobial	Apigen, linalool, luteolin, kaempferol, malic acid, Gallic acid, eugenol, ellagic acid, citric acid, *p*-Propenyl anisole, Catechin, diosmetin, quercetin, naringenin, tricosane, germacrene D, fukiic acid, γ-elemene, β- ocimene, β-caryophyllene, β-farnesene, α-farnesene, phytol, limonene, and camphor	[33,34–36,37,38,39,40,41,42]
		Vicia sativa	Antioxidant, anti-inflammatory and antinociceptive		
		Vicia ervilia	Antioxidative, anti-inflammatory and antiproliferative		
5	***Baphia* Afzel. ex G. Lodd.**	***Baphia nitida***	Anti-inflammatory and antimicrobial	Santal, pterocarpan, maackiain, homopterocarpin, deoxysantarubin, santarubin A, santarubin B, santarubin B, santalin A, santalin B, 1-eicosene, 2,4-dimethoxybenzaldehyde, Homopterocarpin, sativan, medicarpin and Baphianoside	[43,44,45,46]
		Baphia pubescens	Antipyretic, antioxidant and anti-inflammatory	Phytic acid	[47,48]
		Baphia massaiensis	Antimicrobial and anti-inflammatory	Daidzein, Isoafrormosin, 7,3°-dihydroxy-8,4°-dimethoxyisoflavone, pratensein, (+)-catechin, β-sitosterol, stigmasterol, friedelin, friedelin-3α-ol, lupeol, nonadecanoic acid, nonacosane and baphiflavene A	[49,50]
		Baphia leptobotrys	Antileishmanial and cytotoxic activities	Lupenone, lupeol, friedelin, friedelinol, 3-oxofriedelan-29-al, and 3-oxofriedelan-25-oic acid, *β*-sitosterol, stigmasterol, 7-ketostigmasterol, 7-keto-*β*-sitosterol, ergosterol peroxide, daucosterol, *N*-benzoylphenylalaninyl, 4-hydroxy-*N*-methylproline, methyl *β*-D-glucopyranoside, D-mannitol and glycerol tripalmitate	[51,52]
		Baphia kirkii	Anti-inflammatory	Baphikixanthones A, baphikixanthones B, baphikixanthones C, benzophenone, baphikinone, stigmasterol and β-sitosterol	[51]
6	***Mucuna* Adans**	***Mucuna pruriens***	Antidiabetic and anti-neurodegenerative	Indole-3-alkylamines-N, N-dimethyltryptamine, 6-methoxyharman, serotonin gallic acid, lecithin, glutathione and β-sitosterol	[53,54,55]
		Mucuna urens	Antifertility	Physostigmine, levodopa, oxalate and phytate	[56,57]
		Mucuna flagellipes	Anti-obesity and anti-hyperlipidemic	Hexadecanoic acid and 9,12-octadecadienoic acid	[58]
		Mucuna sloanei	Antioxidant, anti-carcinogenic, and hypoglycemic	Phytic acid	[59]
7	***Indigofera* L**	***Indigofera arrecta***	Antiproliferative, antidiarrheal, antibacterial, larvicidal and antidiabetic	Stigmasterol	[60–64,65]
		Indigofera tinctoria	Neuroprotective, antioxidant, antidiabetic, hepatoprotective, immunoprotective, immunostimulating and antidyslipidaemic	Indirubin, indigtone, chrysin, pseudosemiglabrin, semiglabrin, gallatephrin and kaempferol-4',7-dirhamnoside	[66,67]
		Indigofera dendroides	Antinociceptive, antimicrobial and anti-inflammatory	–	[68,69]
		Indigofera lupatana	Anti-epileptic	–	[70]
8	***Macrotyloma* (Wight & Arn.) Verdc.**	***Macrotyloma geocarpum***	Anti-inflammatory, anticardiovascular, antioxidant and antidegenerative	Ferulic acid, procyanidin B2, eryodictyiol-7-rutinoside and quercetin pentoxide	[71]

(*continued on next page*)

Table 1 (*continued*)

S/N	Genus	Species	Pharmacological use	Phytochemical compound	Reference
		Macrotyloma uniflorum	Antihypercholesterolemic, antimicrobial, antiobesity, antihelminthic, analgesic, anti-inflammatory, antilipidemic anticholelithiasis, antioxidant, antiobesity, hepatoprotective, antidiabetic and antihypertensive	Phytic acid, ethyl alpha-d-glucopyranoside, n-hexadecanoic acid, linoleic acid, stigmasterol and 3-beta-stigmast-5-en-3-ol	[72,73,74]

Additionally, about 23–40% carbohydrates and 14–25% fats, 94% of which are in the free form and vitamins A, B_1, B_2, B_3, B_6, B_9, C and E are present in the seeds [79]. Psophocarpin B1, B2, and B3, as well as winged bean proteins present in the P. tetragonolobus plant, have been reported to be similar to soybean lectins [79]. Among the mineral present in the winged bean are calcium, iron, phosphorous, potassium, sulfur, sodium, magnesium, zinc, manganese, boron, barium, copper, chromium and strontium [13]. The oil extracted from winged bean has 30–40% saturated fatty acids which are higher than the content found in soybean oil and better due to its high oxidative and thermal stabilities [13].

In Malaysia, the leaves of the winged beans have been used traditionally in the preparation of compound lotion for the treatment of smallpox and poultice and also to cure vertigo while in Indonesia, the infusion is applied to the eye and ear for the treatment of infections. A feeding trial conducted in Ghana revealed that two children with Kwashiorkor fed with winged beans showed significant clinical progress [80,81]. Many anti-nutritional compounds are found in winged beans, including trypsin inhibitors, chymotrypsin inhibitors (WCI), hemagglutinins, amylase inhibitors, phytate **(1)**, phaseolin **(2),** lectin**,** phytic acid, psophocarpin, tannins, and other phenolic compounds [13]. The chemical structures of the isolated compounds are presented in Fig. 3. The winged bean seed contains between 0.8 and 0.9 mg of gallic acid equivalent to phenols, between 0.7 and 1.2 mg of quercetin equivalent to total flavonoids, and between 1.3 and 1.8 mg of AAE of total antioxidant capacity [82].

Several kinds of research on the pharmacological effects of various winged bean extracts have been undertaken. According to a study, a 75% methanol extract of the plant, as well as it's ethyl acetate and chloroform fractions, n-butanol, petroleum ether, and the methanol extracts of the plant, all showed antioxidant activity, with the ethyl acetate fraction of the methanol extract showing the greatest antioxidant potential and phenolic content [83]. *Pseudomonas aeruginosa* (bacterium) and *Candida albicans* (fungus) have both been shown to be killed and to be inhibited in their growth by the methanol extracts of the leaves and roots of winged beans, respectively. Eleven bacteria, four moulds, and four yeasts were reported to be resistant to the chloroform, ethyl acetate, and ethanol fractions of the winged bean plant, with its pod displaying the most activity and the leaves, the least. The most active fraction was the ethanol fraction, and the least active fraction was the chloroform fraction [14]. Additionally, an *in vivo* toxicity assessment of the extracts in rats showed that they were not toxic at a dose of 2 g/kg as no rats died during the investigation [14]. Using the sulforhodamine B assay, the methanol extract and *n*-butanol fraction of *P. tetragonolobus* exhibited a strong antiproliferative activity on the human colon cancer cell line (HT-29) [15]. The winged bean seed extracts' anti-inflammatory and anti-nociceptive properties demonstrated significant nitric oxide (NO) inhibitory activity upon IFN-/LPS treated macrophages in a concentration-dependent manner without harming the RAW 264.7 cells, and they also prevented mice from writhing to varying degrees of inhibition at 0.2 g/kg [84]. The anti-inflammatory effect of the extracts was attributed to the existence of a peptide that may function as an antagonist for the angiotensin-converting enzyme [85]. Hence, in addition to serving as food, the *P. tetragonolobus* plant could be exploited for its pharmacological properties.

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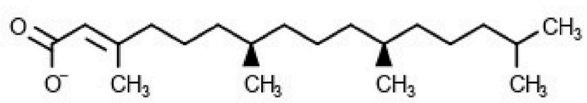

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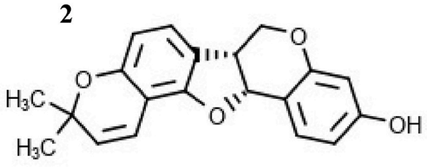

Fig. 3. Structures of compounds isolated from the genus *Psophocarpus*.

3.2. Tylosema (schweinf.) Torre Hillc

The genus*Tylosema* are perennial legume indigenous to Africa and belongs to the Fabaceae family [86]. *Tylosema argentea* (Chiov) Brenan*, Tylosema esculentum* (Burch) A. Schreiber*, Tylosema fassoglense* (Kotschy ex Schweinf.) Torre & Hillc., and *Tylosema humifusa* (Pichi-Serm & Roti-Michael) Brena are the four documented species in the genus *Tylosema* [87]. Out of these four documented species, two main species that have been researched include *Tylosema fassoglense* and *T. esculentum.*

3.2.1. Tylosema fassoglense (kotschy ex schweinf.) Torre & Hillc

Tylosema fassoglense also known as Creeping Bauhinia, Gemsbokboontjie or Sprawling Bauhinia, is a perennial trailing or climbing plant that grows from a large underground tuber [88]. It is a multipurpose plant that provides food, medicine, and other materials to the local communities in sub-Saharan Africa [89]. The seeds are baked, boiled, or roasted in a pan with a little salt for 3–4 min before being consumed as a snack. The seeds have a protein content of over 40% and a fat content of over 30% [90]. The crushed and pounded tubers are used as meals or porridge while the root, in arid climates, serves as a source of water [91]. Traditional medicine uses a variety of plant parts to treat diseases; a decoction of the root is used for the management of some gastrointestinal disorders, including diarrhoea; and also to treat anaemia, fever, pneumonia, and impotence as well as for uterine healing after childbirth. The powdered tubers are employed in the treatment of sexually transmitted diseases, the leaf sap is used to treat middle ear inflammations, and the powdered flower infusions are used to treat jaundice and hypertension [92].

T. fassoglensis seed contains 24–35% (dry weight basis) oil and the physicochemical properties of the oil are identical to the majority of commercial edible oils, making it suitable for human consumption [88]. Linoleic (36–42% fatty acids), oleic (32–35%), and palmitic (11.5–15.7%) acids are the most abundant fatty acids in the oil [93]. The seed is also high in proteins, including lysine, proline, and tyrosine but low in methionine and cystine [93].

The chloroform and methanol extract of *T. fassoglensis* has been shown to possess anticandidal and antimicrobial activities justifying their use in traditional medicine as antimicrobial agent [16]. The aqueous tuber extract of the plant has also been reported for its antibacterial activity [17]. The extract has also been used in herbal formulations to prevent HIV replication in human blood cells [88, 94].

3.2.2. Tylosema esculentum (burch) A. Schreiber

Tylosema esculentum, commonly called Marama or "Green Gold of Africa", is a perennial crop widely distributed in southern Africa, specifically South Africa, Namibia, and Botswana, with a big underground tuber and beans on the creeping part [95,96]. The seeds can be cooked with maize meal or made into flour to prepare porridge or a drink that is similar to coffee or cocoa. The cooked and roasted seeds have a delightful and nutty aroma that is comparable to coffee beans or roasted cashews [97,18]. The beans are known for being high in proteins (29–39%) and oil (24–42%) [18,98–100]. The amount of protein is equivalent to or greater than that of the majority of other legume seeds, such as dry peas, chickpeas, lentils, kidney beans, cowpeas, and lupine, which contain between 20% and 40% dry matter (dm) and are comparable to soybeans (33–46% dm) [98,101]. As a result, it has a great deal of potential for use as a nourishing food as well as a source of dietary supplements. Marama protein is made up of 11% tyrosine, 10% aspartic acid, and 15% glutamic acid

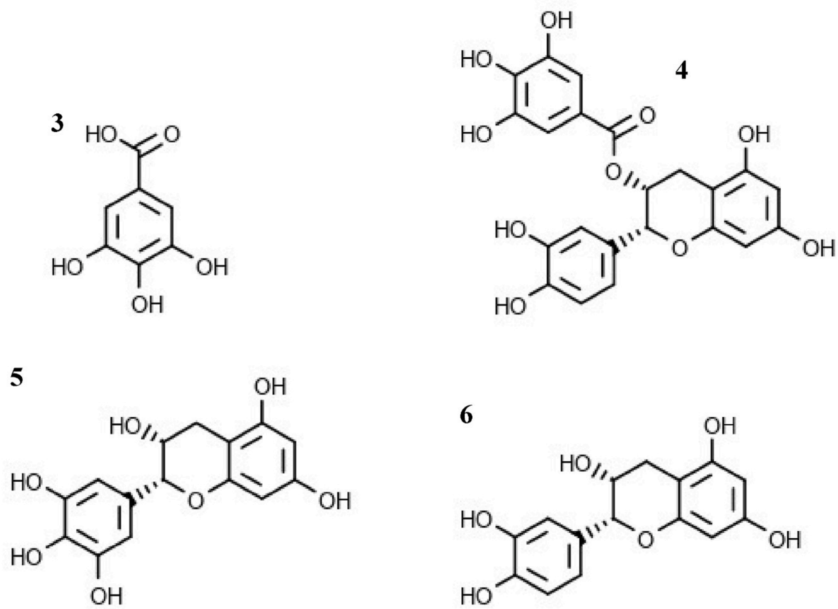

Fig. 4. Structures of compounds isolated from the genus *Tylosema*.

[18,19]. The oil contained in the dry seeds (36–43%) is similar to that of peanuts, with 31% unsaturated fatty acids, primarily oleic acid and linoleic acid [19]. Minerals, including potassium, phosphorus, magnesium, sulfur, and calcium are also abundant in Marama beans [7,19,102,103]. Traditional African medicine has used *T. esculentum* beans and tuber extracts to treat diarrhoea [96,104].

As evidenced by the high multi-species antibacterial and anticandidal activities of *T. esculentum* bean extracts, particularly the phenolic and crude seed coat extracts, at concentrations similar to some conventional antibiotics, the beans are a potential source of microbicides against the bacteria and yeast examined. This was attributed to the phenolic substances isolated from the active fractions, such as gallic acid **(3)**, phytosterols, lignans, certain fatty acids, peptides (specifically protease inhibitors), and amino acids [18,19]. Proanthocyanidins including epicatechin-3-O-gallate **(4)**, epigallocatechin **(5)**, epigallocatechin-3-O-gallate and epicatechin **(6)** isolated from the aqueous extract of the seed coat have also been reported to be responsible for the high DPPH free radical scavenging activity of the plant [20]. The chemical structures of the isolated compounds are presented in Fig. 4.

Additionally, it has been demonstrated that the ethanol extract of Marama beans has significant antiviral activity against rotaviruses, which are frequently responsible for diarrhoea in young children, immunocompromised individuals, and domestic animals [21]. Nitric oxide release, rotavirus inactivation by preventing viral replication or entry into cells, and interference with replication are just a few of the possible antiviral action mechanisms [21].

3.3. *Vigna Savi*

The genus *Vigna* comprises more than 200 species [105]. Over 40 wild and 3 domesticated Vigna species, including cowpea (Vigna unguiculata), Bambara groundnut (Vigna subterranea) and Zombi pea (Vigna vexillate) are found throughout Africa [106]. Small proteins and secondary metabolites that serve as nutraceuticals in daily diets are abundant in the genus *Vigna*.

3.3.1. *Vigna unguiculata (L.) walp*

Vigna unguiculata popularly known as Cowpea is one of the most cultivated species of the genus *Vigna*. It is a staple in Nigerian diets and one of the most significant legumes worldwide [107,108]. Cowpea is widely grown, particularly in the semiarid areas of Africa and Asia where many plants struggle to thrive [109,110]. Nigeria and Niger contribute about 66% of the world's cowpea production, making Africa the region that produces the most of this crop [109,111]. Cowpea seeds are high in proteins and essential amino acids (tryptophan and lysine), as well as carbohydrates, folic acid, and minerals, and have minimal levels of anti-nutritional elements [22,112]. Studies have shown that the type and amount of protein and minerals accumulated in cowpea seeds are influenced by their phenotype which may influence their nutritional and health applications [113,114]. According to one study, most phenotypes were reported to be rich in mono-, di-, and tri (acyl)glycosides of quercetin, whereas myricetin and kaempferol glycosides were found only in certain phenotypes [114]. In ethnomedicine, *V. unguiculata* is used to treat measles, smallpox, adenitis as well as sores [115]. The leaf decoction is used to manage hyperacidity, nausea and vomiting [116–118]. Additionally, some parts of India use a decoction of the seeds ingested orally two times daily for 30 days to dissolve kidney stones [119].

In a study to examine the antioxidant and hypolipidaemic effects of *V. unguiculata,* it was observed that various fermentation techniques, as well as thermal treatment of fermented legume, and flours significantly increased the phenolic content [23]. When compared to a control diet of untreated legumes or casein-methionine, rats fed with the fermented legume flours had significantly higher plasma and hepatic antioxidant activities [23]. *V. unguiculata* has been reported to possess ferric-reducing power and anti-lipid peroxidation potential which were influenced by the total phenolic content, while its total phenolic and total flavonoid content did not affect its free radical scavenging potentials [120]. Cowpea has substantial antioxidant and anti-lipid peroxidation activities which could be beneficial in the prevention and management of some chronic human diseases. *In vivo* study found that polyphenols and flavonoids obtained from the leaves of V. unguiculata had antioxidant, hypolipidemic and anti-atherogenic potentials in ameliorating cholesterol-induced atherosclerosis in rabbits [22,121]. *V. unguiculata* had cardioprotective attributes and thus it was recommended that the inclusion of its leaves in daily diet could help prevent cardiovascular diseases, especially atherosclerosis. The seed oil of three varieties of *Vigna unguiculata* (LBS-1 LBS-2 and LBS-3) was also reported to have antimicrobial activity against five Gram-positive bacteria including *Bacillus megaterium*, *Bacillus subtilis*, *Sarcina lutea*, *Salmonella typhi* and *Staphylococcus aureus* and four Gram-negative bacteria including *Escherichia coli, Shigella dysenteriae, Shigella sonnei, Shigella shiga*. The oils from the three varieties of *V. unguiculata* exhibited antifungal activity against three fungi including *Penicillium* spp.*, Mucor* spp.*, and Candida albicans* [122]. The ethanol and aqueous extracts of cowpea also demonstrated anthelmintic activity comparable with standard antihelminthics against Edriluseuginiae earthworms [123,24]. Both the aqueous and ethanol extracts paralyzed and killed the worms in a concentration-dependent pattern, with the ethanol extract significantly more active than the aqueous extract. Cowpea methanol extract demonstrated antinociceptive activity in mice by decreasing abdominal constriction in acetic acid-induced pain [124]. Furthermore, the seed oil and methanolic seed extract lowered the blood glucose levels in rats with alloxan-induced diabetes and mice loaded with glucose in a dose-dependent pattern [24–26,124]. Two proteins from cowpea seeds, assigned α- and β-antifungal proteins, exhibited antiviral properties by inhibiting human immunodeficiency virus (HIV) reverse transcriptase as well as one of the glycohydrolases linked with HIV infection, -glucosidase [24,27]. The proteins inhibited the growth of the mycelia of several fungi, with the -antifungal protein being the most effective [27]. Cowpea seed extract was found to exhibit a significantly higher antisickling effect than the Hbss control, indicating that cowpea could be a therapeutic agent for the management of sickle cell anaemia [24,125]. The methanol extract of the seeds also showed significant *in vitro* thrombolytic activity indicating its potential use as a fibrinolytic agent to dissolve thrombin in coronary heart disease [126]. *p*-hydroxybenzoic acid **(7)**, catechin **(8)**, and a protocatechuic acid isomer, temporarily identified as dihydroxybenzoic acid have been reported as the most abundant compounds in cowpea seeds' extracts while *p*-coumaric acid **(9)** and several di- and trihydroxybenzoic acids are the major phenolic compounds in pods' samples [127]. The

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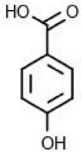

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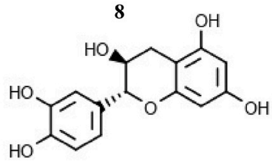

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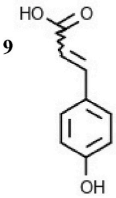

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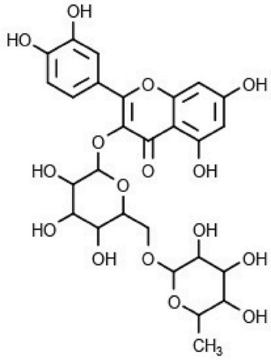

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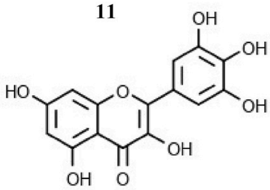

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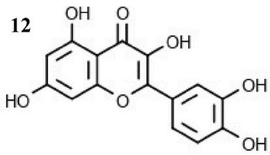

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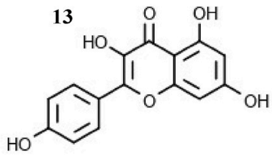

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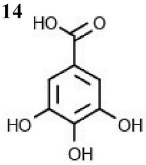

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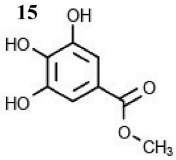

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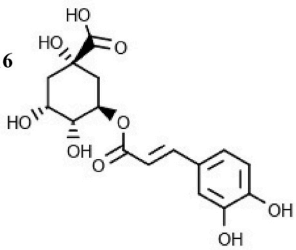

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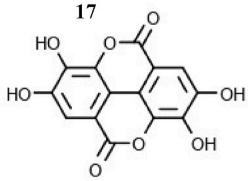

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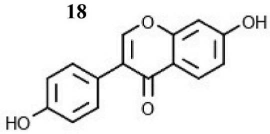

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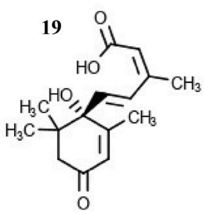

Fig. 5. Structures of compounds isolated from the genus *Vigna*.

chemical structures of the isolated compounds are presented in Fig. 5.

3.3.2. *Vigna subterranea **(L.) verdc***

Vigna subterranea commonly called Bambara groundnut, earth pea, ground bean, or hog-peanut, is a native African legume that naturally grows in Africa's semi-arid areas. It is primarily grown as a subsistence crop, despite its nutritional benefits and resistance to biotic and abiotic stresses [128,129]. It is an essential protein source in the diets of many Africans, especially people who cannot afford meat protein [130]. Bambara protein is high in lysine (6.5–6.8%) and low in methionine (1.8 g per 100 g), both of which are typically deficient in legumes [131,132]. It has been reported that the seeds contain approximately 57–67% carbohydrate, 15–27% protein and lipids (<10%) highlighting their potential to reduce malnutrition and increase food security [28,133].

Flavonoid conjugates found in Bambara groundnut include catechin, quercetin, kaempferol, and apigenin, as well as phenolic acids, saponins, sphingolipids, and fatty acids [29,134,135]. Whole Bambara groundnut seeds' methanol extract had higher flavonol content and considerably better in-vitro antioxidant properties than the hull-free seeds. From the analysis of the total phenolic content of the seeds, monoterpenoids (iridoids), phenolic acids, flavonoids, and lignans were discovered to be present [130]. The extract showed hypoglycemic, hypolipidemic, hepatoprotective, anti-inflammatory, and anti-tumour activities [136,137]. Bambara protein hydrolysates, prepared by digesting Bambara protein isolate with three proteases including alcalase, trypsin and pepsin, and their peptide fraction demonstrated good antioxidant activity that could be useful in preventing food spoilage or treating metabolic disorders linked to oxidative stress [28,30]. The seed extract exhibited a significantly higher antisickling effect than Hbss control, hence, suggesting its usefulness in the management of sickle cell disease [125,138].

Compounds that have been previously isolated from this species include myricetin **(10)**, rutin **(11)**, quercetin **(12)**, kaempferol **(13)**, gallic acid **(14)**, catechin, methyl gallate **(15)**, chlorogenic acid **(16)** and ellagic acid **(17)** [29]. The chemical structures of the isolated compounds are presented in Fig. 5.

3.3.3. *Vigna vexillata (L.) A. Rrch*

V. vexillata (Zombi pea), despite being broadly distributed in Africa, Asia, America, and Australia, is among the least known and underused *Vigna* species [22]. Zombi pea, like other *Vigna* species, has a high morphological diversity, which is likely due to geological, ecological, climatic, and artificial constraints, which have resulted in exceptional patterns of genetic variability [22].

The antioxidant and free radical-scavenging abilities of raw and processed Zombi pea seeds using 70% acetone have been reported [31]. The methanol extracts of V. vexillata and three molecules isolated from the active chloroform fraction namely, daidzein **(18)**, abscisic acid **(19)** and quercetin, showed remarkable anti-inflammatory activities when compared to the PI3K inhibitor, LY294002 and the NADPH oxidase inhibitor, DPI [32]. The phosphatidylinositol-3-kinase (PI3K)/protein kinase B (AKT) pathway is well recognized to play a significant role in neutrophil activation, and the NADPH oxidase enzyme is also involved in the inflammatory process. Thus, the extracts and purified compounds were very potent and showed a crucial ability to block the inflammatory pathway; as such, they could be used as phytochemical lead molecules from plant-derived foods for the development of an anti-inflammatory agent [32].

3.4. *Vicia L*

The genus *Vicia* has about 150–210 species spread across Europe, Asia, and North America, with the majority of them found in the Mediterranean [139–141]. They are essential to sustainable agriculture because *Vicia* species are valuable grain and forage crops from an economic standpoint. Both humans and animals can use them as a less expensive protein and energy source [142]. However, some *Vicia* species' seeds produce toxins and antinutritional molecules, limiting their use as food (humans) and feed (animals) [143]. The species, which are abundant in secondary metabolites, have been used to treat and manage several diseases. In Turkish traditional medicine, *Vicia* species are used to treat malaria, diarrhoea, haemorrhoids, kidney diseases, and infertility in women [144,145]. *Vicia* species are used in ancient veterinary medicine in Italy to treat gastrointestinal problems and as food supplements [146]. Some phenolic compounds, such as condensed tannins and flavonoids, have been linked to a variety of pharmacological activities, including antioxidant, anti-inflammatory, antinociceptive, chemopreventive, antimicrobial, and anthelmintic [33,147]. These species contain lectins, flavonoids, condensed tannins, procyanidins, and saponins, according to phytochemical studies [148–150]. Among the *Vicia* species, several flavonoid aglycones (apigenin, luteolin, kaempferol, quercetin, myricetin, diosmetin, and vitexin) and glycosides (apigenin glucopyranoside, luteolin glucopyranoside, kaempferol dirhamnopyranosyl glucopyranoside, quercetin glucopyranoside), have been isolated [33,148,151].

3.4.1. *Vicia faba L*

Vicia faba also known as faba bean, broad field bean, and horse bean is a cool-season grain legume crop that originated in prehistoric times in the Middle East and has since spread throughout the world. As a result of its high nutritional and therapeutic values, it has historically been used as the principal protein source for humans and animals [152]. *V. faba* is widely regarded as one of the very essential staple crops for human nutrition [153]. Due to its abundant proteins, complex carbohydrates, dietary fibre, choline, lecithin, minerals, and secondary metabolites, including phenolic compounds, and nearly all other nutrients needed in human diets, it is one of the most significant pulse crops, globally [154,155]. Faba bean seeds typically have low fat, sodium, and cholesterol content [156]. Ancient Greece and Rome traditionally used *V. faba* as a diuretic, expectorant, and tonic [157]. In Southern Spain, the leaves are used to treat acne, burns, and infections of the nail [158], while the seeds are used in the Canary Islands (Spain) to treat burns and anaemia [159]. Faba bean fruits are consumed raw in Turkey, and the seeds and fruits are used as a depilatory and a diuretic in Bilecik City [160] while the leaves are applied for the treatment of Alzheimer's disease [161]. *V. faba* aerial parts are also used as a carminative to treat constipation, intestinal spasm, dyspepsia, and athetosis [161]. The plant's powder, decoction, and infusion have all been employed in Morocco to treat several ailments, such as diabetes, allergies, and respiratory issues [162].

Faba beans are high in polyphenols, which are responsible for their health benefits. Faba beans have a high concentration of l-3,4-dihydroxyphenylalanine (L-DOPA) in their seedlings, pods, and beans [163]. L-DOPA is a precursor to dopamine, which is presently used in the treatment of Parkinson's disease and hormonal imbalances [163,164]. *V. faba* has been suggested as a natural source of L-DOPA, which may be helpful in the treatment of Parkinson's disease. This can be used to replace the synthesized L-DOPA which has been linked to many side effects, including nausea, vomiting, low blood pressure, drowsiness, and restlessness, as well as high cost [165–167]. The presence of total phenolic and total flavonoid contents has been linked to the antioxidant properties of *V. faba* extracts. The antioxidant activity of faba beans, determined using ABTS and FRAP assays, was higher than that previously reported for the extracts of other legume seeds [168]. In comparison to synthetic antioxidant compounds, even at high concentrations, *V.* faba has been cited as a natural source of antioxidant proteins with no negative side effects. From the protein hydrolysate of faba bean seeds, three peptides with high DPPH radical scavenging activity have been found (IC_{50} = 0.25–1.9 mM) [34]. Choudhary and Mishra [35], investigated the α-amylase inhibitory activity of the crude seed extracts of *V. faba* and reported that the acetone and methanol extracts of the seeds significantly inhibited the activity of the α-amylase enzyme with IC_{50} values of 2.94 and 5.27 mg/mL, respectively. Several peptides possessing antimicrobial properties have been isolated from *V. faba*. Ye and Ng [36], isolated a protease inhibitor from the plant. The reverse transcriptase of the human immunodeficiency virus type 1 was suppressed (IC_{50} = 32 μM) by this protein and had antifungal effects on *Mycosphaerella arachidicola* and *Physalospora piricola*. Additionally, a trypsin inhibitor from the plant was isolated and demonstrated antifungal activity against the fungus, *Valsa mali* (IC_{50} = 20 μM) [169].

3.4.2. Vicia sativa L

Vicia sativa known as Vetch, Garden Vetch, or Tare, is a nitrogen-fixing crop that is commonly cultivated in Egypt and Australia [170]. It is a sprawling annual herb with hollow, quadrilateral, hairless to thinly hairy stems up to 2 m in length. The seeds have a yield of up to 250 kg/ha and are commonly used for animal feed and consumed by rural populations in many countries [171]. Many studies reported that *V. sativa* forage is a rich source of protein for animals [172–174]. Vetch leaf decoction has traditionally been consumed as a blood tonic and to treat asthma, bronchitis, urinary diseases, and skin infections [175]. *V. sativa* seed flour is used in Lebanon for the treatment of rheumatism [176] and as an analgesic in America [177].

Gamal-Eldeen et al. [33] established the ethanol extract of *V. sativa* aerial parts' antioxidant activity against the free radicals 2, 2-diphenyl-1-picrylhydrazyl (DPPH), superoxide anion, and peroxyl and attributed this activity to the purified flavonoids in the extract. The antioxidant potential of Vetch polyphenolic extract was established through *in vitro* antioxidant activity using the β-carotene bleaching assay [178]. The findings also revealed that *V. sativa* polyphenolic extract had a significantly greater radical scavenging activity in the DPPH assay than butylated hydroxytoluene (BHT) (IC_{50} = 4.5 μg/well) [179]. The antiproliferative properties of Vetch seed ethanol extracts were investigated using the human monocytic THP-1 cell line. The extract at doses between 10 and 20 μg/mL increased cell death on days 3 and 4 [179]. An investigation of the *in vivo* anti-inflammatory potential of the ethanol extract of *V. sativa* aerial parts showed that the extract exhibited inhibitory activity that ranged from 11.5 to 24.6% against various inflammatory and nociceptive mediators [33].

3.4.3. Vicia ervilia (L.) wild

Vicia ervilia, also known as Bitter Vetch or Ervil, is a hermaphrodite annual herb with a maximum height of 0.6 m. The plant is indigenous to the ancient Mediterranean area [37]. The cultivation of bitter vetch has resulted in the production of edible seeds [180], which can also be used directly as forage or processed into a good source of protein for poultry [181,38]. *V. ervilia* seeds are used for palliative, aphrodisiac, and salutiferous purposes [37]. Bitter vetch is used to treat pathologies of the digestive system, allergies, and general weakness in both macerated and powder forms. Vetch seeds and their decoctions are used for hypoglycemia in Turkey [182]. Warm *V. ervilia* decoction baths and over-fire-wilted leaves are used to treat rheumatism [182]. *V. ervilia* has been used to treat cancer in the Middle East [183].

An *in vivo* study of the anti-inflammatory potential of *V. ervilia* seed ethanol extract showed that the extract displayed remarkable anti-inflammatory activity by reducing carrageenan-induced oedema by 24.5% of its initial volume. The extract was not toxic to the animals, implying that bitter vetch could be a safe alternative to commonly used anti-inflammatory drugs [38]. Vioque, Girón-Calle, Torres-Salas, Elamine and Alaiz [37] showed that extracts of *V. ervilia* seeds exhibited antioxidant effects ($p < 0.001$) in a concentration-dependent manner. The extracts displayed antiproliferative effects ($p < 0.001$) in a Caco-2 cell line, obtained from a tumour cell. The antioxidative and antiproliferative activities were both linked to the polyphenol contents of the extracts [37].

The genus *Vicia* has been reported to contain flavonoids such as apigen **(20)**, linalool **(21)**, naringenin **(22)** and quercetin **(23)** [39, 184,185] as well as the O-methylated flavone, diosmetin **(24)** [40]. Catechin **(25)**, a polyphenol and other phenols and phenolic compounds such as *p*-Propenyl anisole **(26)** [186], citric acid **(27)**, ellagic acid **(28)**, eugenol **(23)**, Gallic acid **(30)** [187,41], malic acid **(31)**, palmitic acid **(32),** salicylic acid **(33)**, syringic acid **(34)** [186,42], have also been found to be present in some of the species of this genus. Some glycosides were also reported to have been previously isolated from the *Vicia* genus. These include kaempferol **(35)** and luteolin **(36)** [185,186,188]. Previous investigations on the species of this genus also indicated the presence of some terpenoids such as juniper camphor **(37)**, limonene **(38)**, phytol **(39)**, α-farnesene **(40)**, β-farnesene **(41)**, β-caryophyllene **(42)** and β-ocimene **(43)** [40,186] and some carbonyl compounds such as phytone **(44)** and γ-elemene [186,189]. Other compounds isolated from this genus are fukiic acid **(45)** germacrene D **(46)** and tricosane **(47)** [40,41]. The chemical structures of the isolated compounds are presented in Fig. 6.

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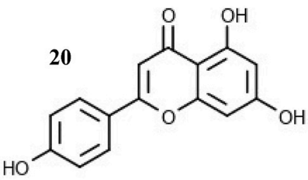

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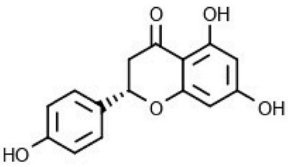

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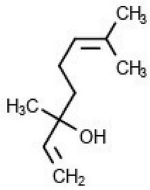

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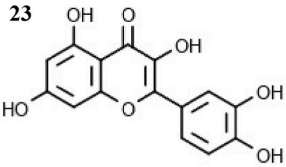

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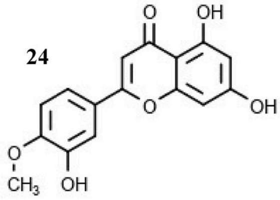

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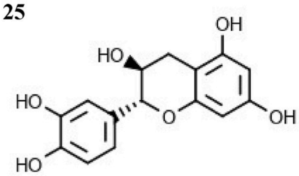

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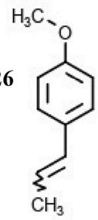

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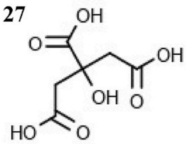

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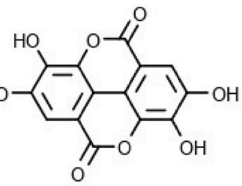

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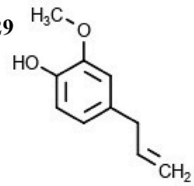

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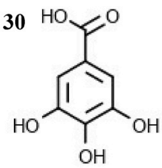

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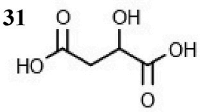

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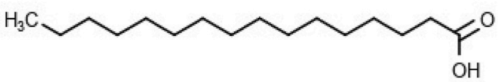

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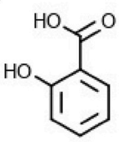

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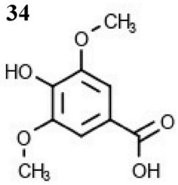

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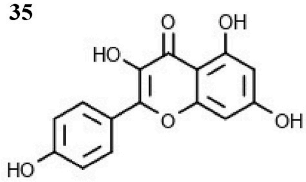

Fig. 6. Structures of some compounds isolated from the genus *Vicia*.

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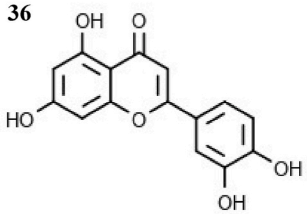

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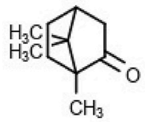

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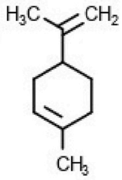

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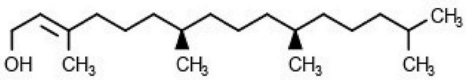

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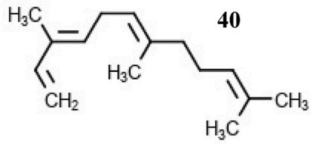

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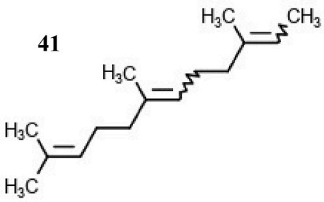

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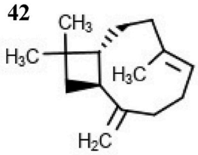

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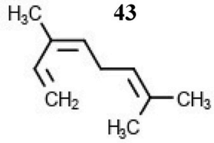

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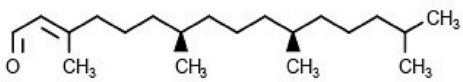

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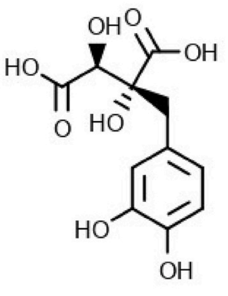

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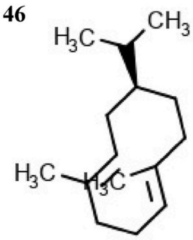

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Fig. 6. (*continued*).

3.5. Baphia Afzel. ex G. Lodd

Baphia is a small legume genus with simple leaves [190,191]. It is a genus with approximately 48 shrubs, distributed across Africa and Madagascar [191,192]. It is a poorly documented and researched genus adapted and grown only in the west African region with no existing seed supply system and no external input in production, which makes the genus very underutilized and less recognized [193, 194].

3.5.1. *Baphia nitida lodd*

Baphia nitida, also known as camwood, barwood, African sandalwood, *Osun* (Yoruba, Nigeria) and *Onwono* (Asante Twi, Ghana), is a diminutive, understorey, evergreen tree that is frequently found in villages and reaches a height of about 9 m [195,196]. The tree is commonly used as a decorative or shade tree in communities, as well as a source of medicines and dye [196,197]. The wood is very

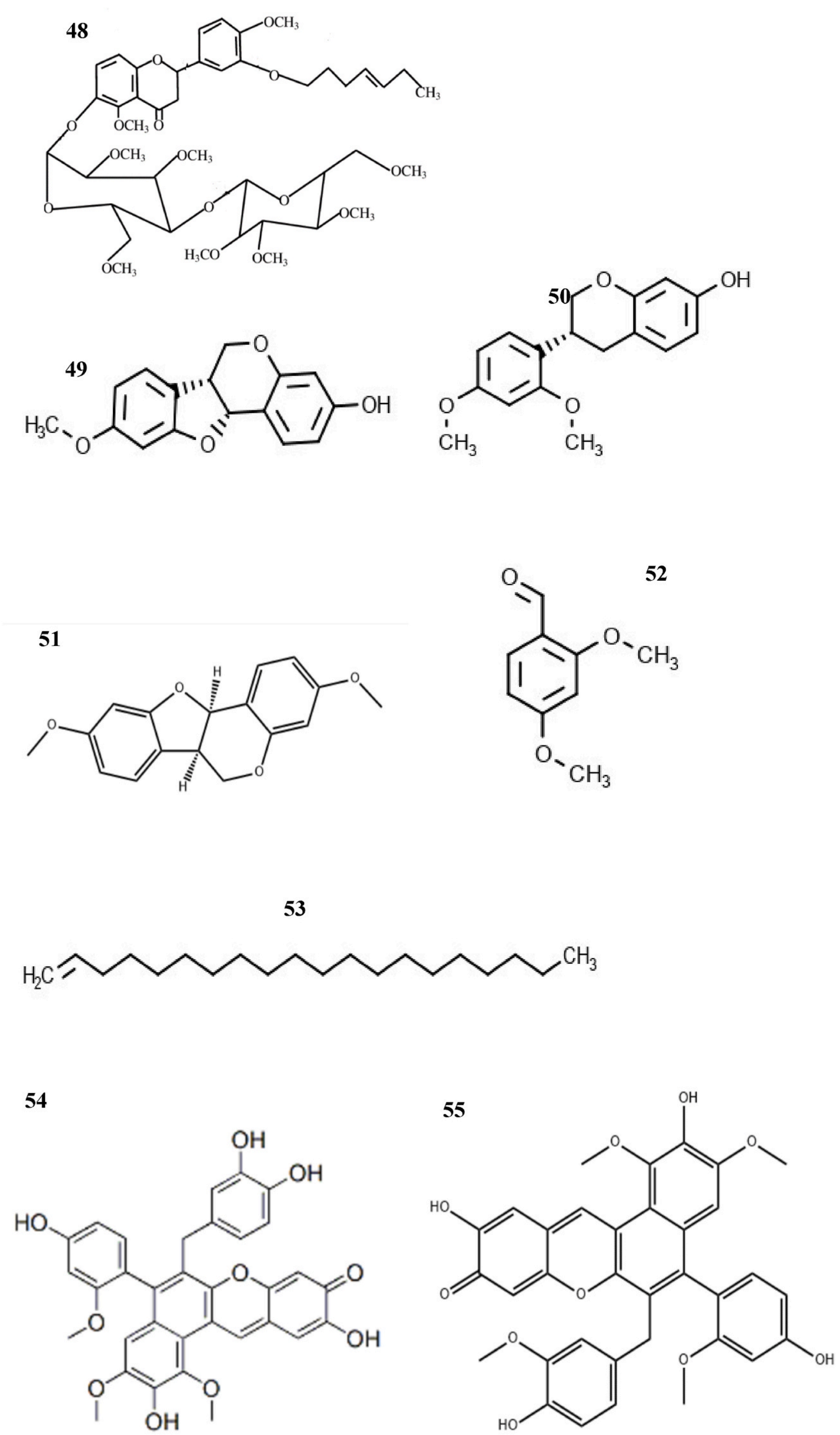

Fig. 7. Structures of compounds isolated from the genus *Baphia*.

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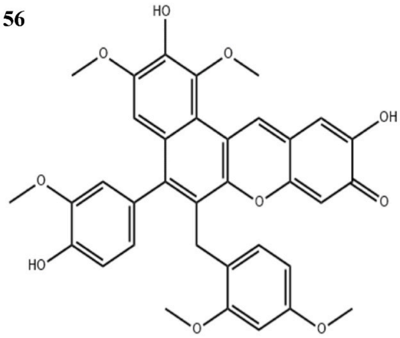

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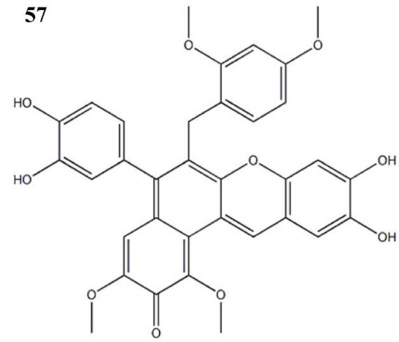

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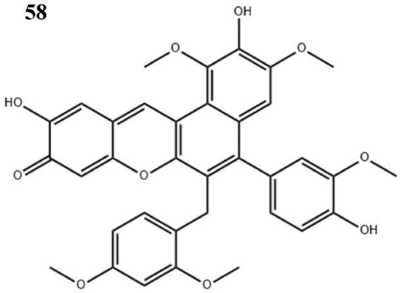

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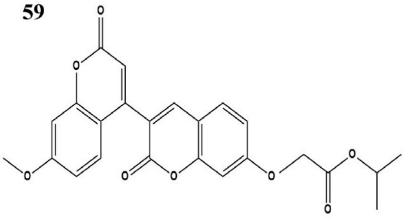

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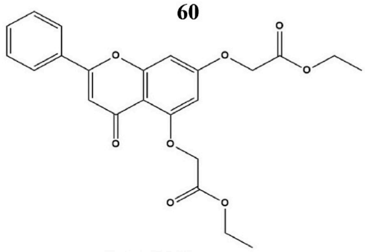

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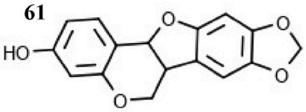

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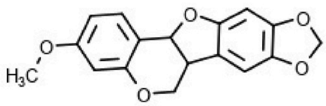

Fig. 7. (*continued*).

finely coloured and used in woodturning to create knife handles and other items of a similar nature. The bark and heartwood of the tree are frequently used to create a brilliant but temporary red dye that is soluble in alkali [198]. In addition, some soaps and skin care products contain *Osun* (camwood) extract, which is primarily used by the Yoruba people of West Africa. Camwood extract can be transformed into a gentle soap-like substance that is thought to support healthy skin. The tree is revered in some areas because it can both repel evil spirits and attract good ones. The *Tiv* people of Nigeria use the red dye to stain the interior of a gourd that has been prepared as a beehive to entice bees to settle there, and Yoruba honey-hunters rub the paste on their bodies to protect themselves from bee stings [199,200]. It was one of the main "redwood" dyes used to colour wool, cotton, and silk that were widely exported to Europe beginning in the 17th century and to North America beginning in the 18th century. The dyers in Europe and America believed it had a colouring strength three to four times greater than the other redwoods they were using, which were "insoluble" [201].

Indigenous people from many West African nations have used different parts of *B. nitida* for a variety of ethnomedical and ornamental purposes. *B. nitida* is commonly chewed on by locals to treat toothaches and female fertility. Additionally, it is used in the treatment of gastrointestinal issues, ringworm, sprains and swollen joints, parasitic skin conditions, wounds, ulcers, and boils [202, 203]. The leaves and bark are used to treat wounds as well as inflamed and infected umbilical cords in Ghana, Côte d'Ivoire, and Nigeria because they are thought to be hemostatic and anti-inflammatory. In Ghana, the stem and leaves are used to treat dysentery, ringworm infections, and venereal diseases. The entire plant is used in the Ivory Coast to treat amenorrhea and female sterility, while

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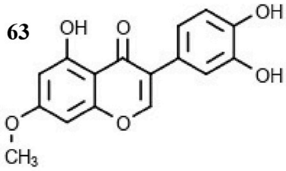

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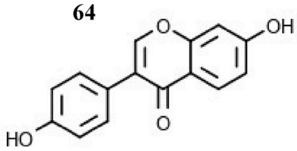

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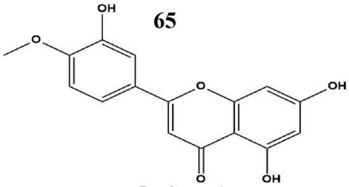

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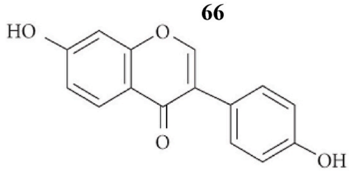

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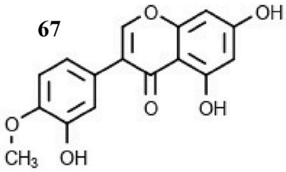

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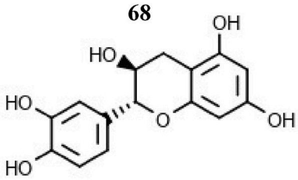

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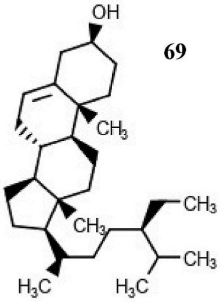

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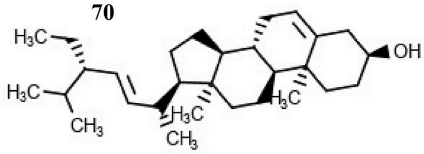

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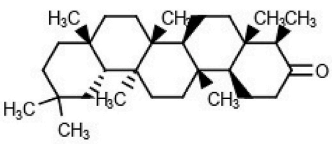

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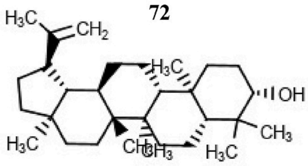

Fig. 7. (*continued*).

the leaf juice is used to make eye drops for jaundice and eye infections [204]. The wood and leaf infusions are also used in Nigeria as local hemostatic agents and the cold-water extract of the fresh leaves has allegedly been used to calm the heart and reduce palpitations. When combined with shea butter, the powdered heartwood is made into an ointment that is applied to sprains, stiff and swollen joints, and rheumatic complaints while asthma is treated with honey and finely ground root bark of the plant [205]. A mixture of ground dried root, water, and oil is used in the treatment of fungus feet similar to ringworm [203,204].

To demonstrate the ability to prevent the rodents' inflammatory condition, a chromatographically isolated flavonoid-rich fraction of the leaf was made into an ointment and tested for anti-inflammatory activity against croton oil and inflammation induced by heat in the ears [206]. It was discovered that the dose-related activity significantly outperformed the positive control, Hydrocortisyl cream. This justifies the plant's leaves being used traditionally as an anti-inflammatory agent [206]. The leaves and root extract of the plant

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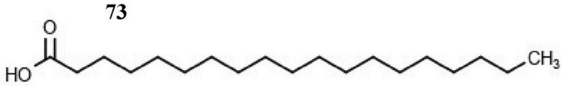

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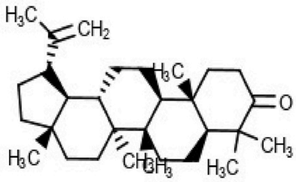

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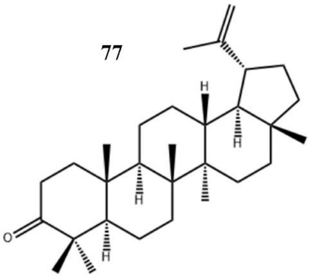

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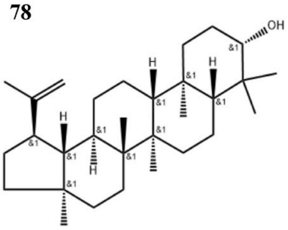

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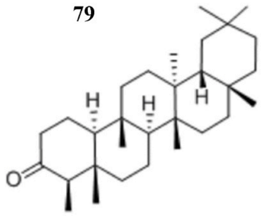

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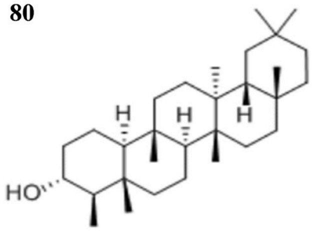

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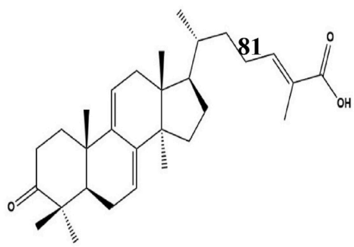

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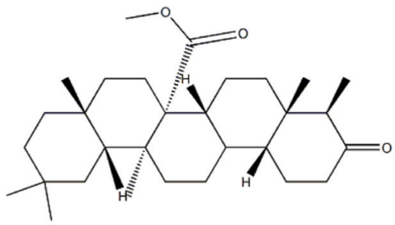

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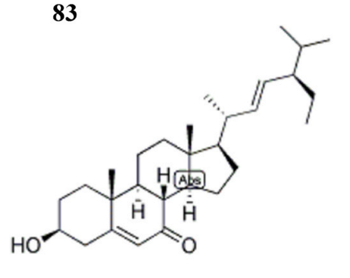

Fig. 7. (*continued*).

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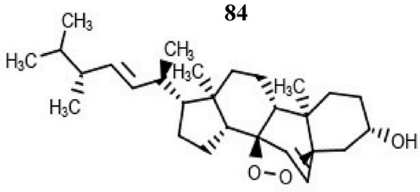

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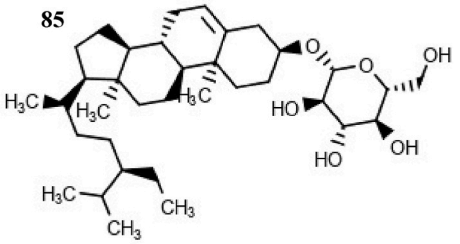

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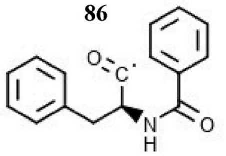

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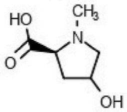

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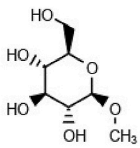

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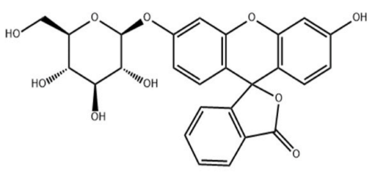

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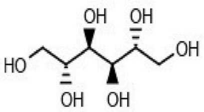

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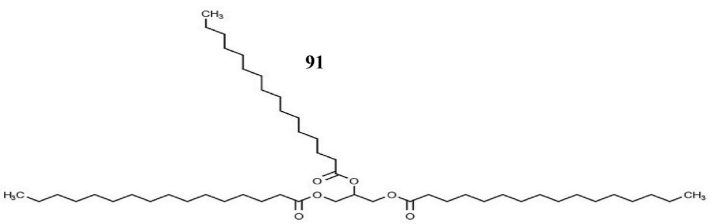

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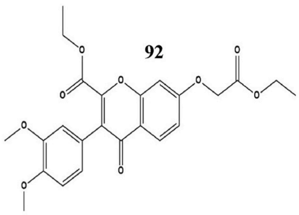

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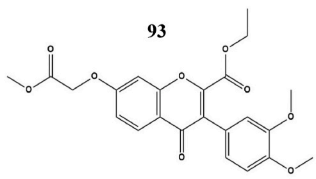

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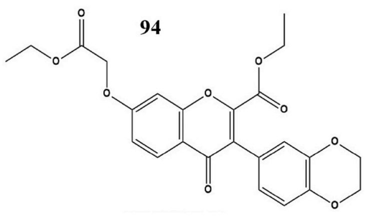

Fig. 7. (*continued*).

showed a significant anti-inflammatory effect at low concentrations between 25 and 75 mg/kg body weight in the carrageenan-induced paw oedema model [203]. The antimicrobial activities *of B. nitida* have also been confirmed by several authors [43,207]. Four aqueous extracts of *B. nitida* dyes were tested for their antimicrobial activity against five clinical isolates of *Staphylococcus aureus*, *Escherichia coli*, *Bacillus cereus*, *Proteus vulgaris*, and *Pseudomonas aeruginosa* using the agar diffusion, disc diffusion, and agar dilution methods. The results showed that the extracts inhibited the test organism at a minimum inhibitory concentration (MIC) of 37.5 mg/mL [44]. The antimicrobial effectiveness *of B. nitida* extracts cream and ointment outperformed that of traditional antiseptic creams and ointments [208].

B. nitida has been reported to contain Baphianoside **(48)** [209], isoflavonoids known as medicarpin **(49)** and sativan **(50)**, tannins, flavonoids, terpenoids and saponins, glycosides, alkaloids, anthraquinones, cardiac glycosides and phlobatanins [196,210]. In a study on the methanol extract of *B. nitida* heartwood, it was reported that an isoflavonoid called Homopterocarpin **(51)** and a terpenoid called 2,4- dimethoxybenzaldehyde **(52)** had been isolated [196]. Another study on the chloroform extract of the leaves of *B. nitida* led to the isolation of 1-eicosene **(53)**, a substance that has been isolated from other plant species but was discovered in *B. nitida* for the first time [195]. Also, a previous investigation on *B. nitida* indicated the presence of isoflavonoids-flavonoids dimer santalin A **(54)** and santalin B **(55),** and santarubin A **(56)**, santarubin B **(57)** and santarubin C **(58),** deoxysantarubin **(59),** homopterocarpin **(60),** maackiain **(61),** pterocarpin **(62)** and santal **(63)** [45,46]. The chemical structures of the isolated compounds are presented in Fig. 7.

3.5.2. Baphia pubescens Hook.F

Baphia pubescens, commonly referred to as Benin camwood, *Awewi, Urohun*, and *Maajigi* (Yoruba) is similar to *Baphia nitida*, and their common names and uses are largely interchangeable. The hairy ovary and hairy leaves of *B. pubescens* set it apart from *B. nitida*. Its heartwood is also a source of red dye, though it is less popular. It is typically found in the majority of African nations, including Nigeria, Togo, Ghana, Liberia, Zaire, Congo, the Ivory Coast, Cameroon, Gabon, and the Benin Republic [47,48,211]. It is used by people historically as a powerful medication to treat enteritis and other gastrointestinal infections. Rheumatism and arthritis are both managed with the bark; the oil is used to treat kidney conditions and as a diuretic, and the sap is used as an eye treatment [212]. Although, the wood of *B. pubescens* is used for furniture and similar purposes, the chemical products made from it, such as dyes, stains, inks, tattoos, and mordants, also have tremendous economic value. There is limited information on *B. pubescens* despite widespread claims of its enormous importance [211].

The leaves of *B. pubescens* exhibited antipyretic activity in brewer's yeast pyrexia, by reducing the temperature at which brewer's yeast pyrexia develops in rats [47,48]. Steroids and tannins were present, but alkaloids, flavonoids, saponins, and carbohydrates were absent [47,48].

3.5.3. Baphia massaiensis taub

Baphia massaiensis also called Jasmine pea or Sand Camwood is a small tree with a height of 2–4 m. It is prevalent throughout most of western, central, eastern, and southern Africa, including Botswana [49]. It is a relatively small tree or shrub that can reach up to 10 m in height. It is an incredibly variable species that can be distinguished from *Baphia nitida* by its long bracteoles, pubescent ovary, and typically rounded or obtuse leaf apex. The tree branches are occasionally used to make toothbrushes. In northern Namibia, the roots serve as a source of red dye for leather hides [213]. Some reports claim that the seed can be roasted, and then pulverized and used as a coffee substitute [214]. Like most *Baphia* species there is a dearth of information on *B. massaiensis.*

The single most important compound isolated from the leaves of *B. massaiensis* var. obovate was previously identified as daidzein **(64)** [49,50]. However, according to a recent study, fourteen other compounds have been isolated and characterized from the stem bark and twigs of *B. massaiensis*, of which the structures of two have not yet been established. Eleven of the compounds which include Isoafrormosin **(65)**, 7,3°-dihydroxy-8,4°-dimethoxyisoflavone **(66),** pratensein **(67)**, (+)-catechin **(68),** β-sitosterol **(69),** stigmasterol **(70),** friedelin **(71),** friedelin-3α-ol **(72),** lupeol **(73)**, nonadecanoic acid **(74)**, and nonacosane **(75)** were isolated for the first time in the species, despite having been found in other plant species before while baphiflavene A **(76)** a novel compound was discovered for the first time in *B. massaiensis* [49]. The chemical structures of the isolated compounds are presented in Fig. 7.

3.5.4. Baphia leptobotrys harms

Baphia leptobotrys is a shrub that is occasionally scrambling, lianescent or arborescent with glabrous branches and leaves that are primarily oval, oblong-elliptic or rounded at the base and broadly acuminate at the top [191,215]. In the Dja biosphere of Cameroon, a decoction of its stem bark has reportedly been taken orally to treat jaundice [215].

Nineteen compounds, including eight triterpenoids, were isolated through chemical analysis of *B. leptobotrys* extracts from the trunk, bark, and leaves. These compounds include lupenone **(77),** lupeol **(78),** friedelin **(79),** friedelinol **(80),** 3-oxofriedelan-29-al **(81)** and 3-oxofriedelan-25-oic acid **(82)** [49,51], six steroids; *β*-sitosterol, stigmasterol, 7-ketostigmasterol **(83),** 7-keto-*β*-sitosterol **(84)**, ergosterol peroxide **(85)** and daucosterol **(86)** [51,216,217], two amino acids; *N*-benzoylphenylalaninyl **(87)** and 4-hydroxy-*N*-methylproline **(88),** two sugars; methyl *β*-D-glucopyranoside **(89)** and D-mannitol **(90)** [51,218] and one glycerol derivative; glycerol tripalmitate **(91)** [51]. The chemical structures of the isolated compounds are presented in Fig. 7. Glycerol tripalmitate, which had previously been synthesized, was isolated from the species for the first time [52].

3.5.5. Baphia kirkii baker

Baphia kirkii is a much-branched tree with a rounded canopy and pendulous branches, reaching up to 27 m tall with deeply fluted irregularly-shaped bole [92,191,219]. *B. kirkii* is a locally favoured source of timber often harvested from the wild and it is also cultivated for ornament and shade [220]. It is found in Mozambique, Tanzania, and possibly Kenya [191]. The habitat of this species has suffered from conversion to agriculture and local exploitation and as such is categorized as 'Vulnerable' in the IUCN Red List of Threatened Species (2011) [221]. A root decoction of *B. kirkii* is consumed orally to manage epilepsy [191].

There are very few studies on the phytochemical components and pharmacological uses of *B. kirkii* despite the extensive research that has been conducted on Fabaceae plants. Three new prenylated xanthones, baphikixanthones A **(92)**, baphikixanthones B **(93)** and baphikixanthones C **(94)** as well as benzophenone, baphikinone, and two common steroids, stigmasterol and β-sitosterol, were

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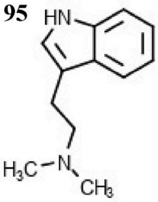

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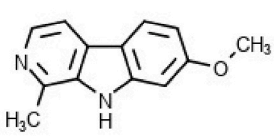

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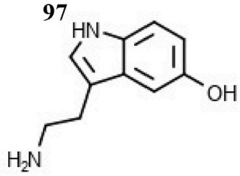

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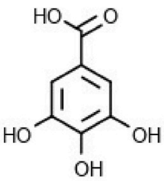

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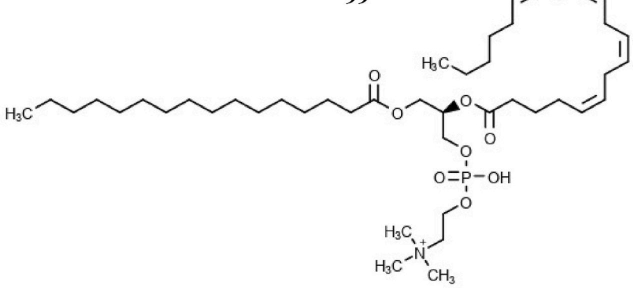

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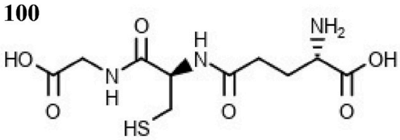

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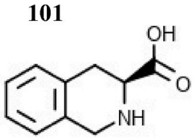

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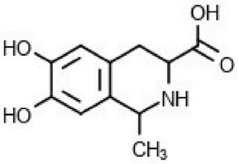

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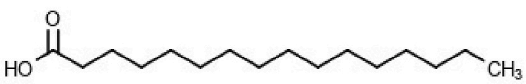

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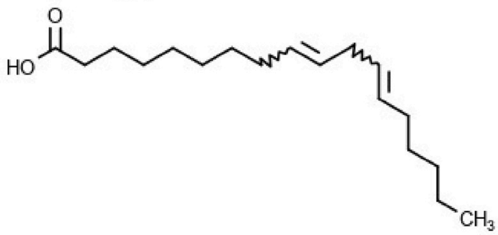

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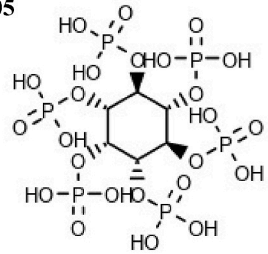

Fig. 8. Structures of some compounds isolated from the genus *Mucuna*.

reported to have been isolated from the ethanol extract of the whole stem of *B. kirkii* [222]. The chemical structures of the isolated compounds are presented in Fig. 7. Additionally, the presence of related compounds in some of the *Baphia* species mentioned here suggests that the species are closely related phylogenetically [223].

3.6. Mucuna Adans

A significant plant genus in the Fabaceae family is *Mucuna* [224,225], which got its name from the word "mucuna," which refers to the clustering flowers, is widespread in tropical woodlands, notably in tropical Africa, India, and the Caribbean [226]. Most *Mucuna* species thrive in a shady environment with humus-rich, hydrated but well-drained soil [227]. *Mucuna* is on the red list of IUCN underutilized legumes and has also been reported as the second largest family of flowering plants which are climbing vines and shrubs with 600 genera and around 12000 species [228]. Most species of *Mucuna* are twining herbaceous plants originating in the tropical areas of the world, especially Africa. Their leaves are trifoliate and unequal at the base, with white to dark purple flowers existing in long clusters. The pods are turgid, sigmoid and longitudinally ribbed with reddish-orange hairs that are easily displaced and cover the surface. The seeds of *Mucuna* are generally ovoid, black or white and can have different botanical characteristics depending on their accessions [229]. Most *Mucuna* species are in increasing demand wherever they are found because of their nutraceutical potential and possible pharmaceutical usefulness [224]. The genus has the potential to be a promising food source that could help with severe food shortages if properly promoted and researched. *Mucuna* is a rich source of amino acids, protein, carbohydrates, minerals, lipids and fibre. However, the accessions and different species are high in minerals but low in crude fibre. The minor chemical variations between the various *Mucuna* species may be brought on by the various seed coats [230]. *Mucuna* seeds contain oils which could be exploited for industrial use. *Mucuna pruriens* and *Mucuna urens* are outstanding species of this genus because of their pharmacological properties [231].

3.6.1. Mucuna pruriens linn

Mucuna pruriens, commonly known as cowage, lacuna bean, Lyon bean, Florida velvet bean, Mauritius velvet bean, Bengal velvet bean, Yokohama velvet bean and *Werepe* (Southwestern Nigeria), is infamous for giving off a severe itch when touched, especially when the young leaves and seed pods are involved [232]. In Nigeria, the seed pods are referred to as "Devil Beans" because of their itching properties. The calyx beneath the flowers is another source of itchy spicules and along with itching, it causes numerous medium-sized red, swollen bumps. It has agricultural, horticultural and healing properties and the seeds have been used to treat sexual dysfunction [233]. The plant extracts have been used as an antidote for snake bites [234,235] and for the treatment of Parkinson's disease [236]. The bean paste has been reported to absorb poison from scorpion stings and to have a high content of DOPA [237]. Serotonin and mucunain which are proteins are found in the hairs that line the seed pods [232].

M. pruriens seeds also contain some toxic and anti-physiological factors which lower their overall nutritional quality such as polyphenols which lower the digestibility of proteins by binding to them and phytic acid which is a major component which lowers the bioavailability of iron, zinc, calcium, phosphorus and magnesium [238]. The plant contains various proteins and amino acids such as tyrosine, phenylalanine, threonine, proline, serine, histidine, tryptophan, lysine, and arginine in addition to its high starch content [239]. This legume is considered a recuperative herb due to its several biological activities. Indole-3-alkylamines-N, and N-dimethyltryptamine **(95)** are found in the pods, seeds, leaves, and roots [240]. 6-methoxyharman **(96)** is found in the leaves while serotonin **(97)** is only found in the pods. The seeds contain oils, including linoleic, stearic, oleic, and palmitic acids. *Mucuna* seeds are famous for producing the unique anti-nutrient non-protein amino acid, 3-(3,4 dihydroxyl phenyl)-l-alanine (l-Dopa), a strong neurotransmitter precursor believed to be the cause of the seeds' toxicity [53,241]. The whole pod of *M. pruriens* contain about 4% L-Dopa. It also contains some other compounds such as gallic acid **(98)**, lecithin **(99)**, glutathione **(100)**, and β-sitosterol. Four alkaloids L- 3-carboxy-1, 2, 3, 4- tetrahydroisoquinoline **(101)**, (−)- 1- methyl- 3carboxy- 6, 7- dihydroxy- 1, 2, 3, 4- tetrahydroisoquinoline **(102)**, dimethyl-3carboxy- 6, 7- dihydroxy- 1, 2, 3, 4- tetrahydroisoquinoline and (−)- 1- 3- carboxy- 1, 1- dimethyl- 7, 8- dihydroxy- 1, 2, 3, 4- tetra hydroisoquinoline are found in the seeds of the plant [240]. The chemical structures of the isolated compounds are presented in Fig. 8.

Majekodunmi *et al* [54]reported the antidiabetic activities of *M. Pruriens* ethanol seed extract in comparison with glibenclamide (standard drug). The safety of the extract using acute toxicity studies was also reported and oral administration improved weight loss which is associated with diabetes in the experimental animals. According to a study in alloxan-induced diabetic rats, *M. pruriens* ethanol seed extract exhibited both hepatoprotective and lipogenic activities [55]. *M. pruriens* seed extract tablets exhibited anti-diabetic properties similar to the reference drug, glibenclamide, in alloxan-induced diabetic rabbits. The result revealed no significant ($p > 0.05$) difference in blood glucose level achieved with *M. pruriens* tablets and glibenclamide, which further confirms that *M. pruriens* extract can be formulated into tablets and used for the management of diabetes [242]. Furthermore, the L-DOPA in Mucuna beans can be used in Alzheimer's disease prevention by hindering A and tau aggregation [243]. When compared to the control group, mice fed the bean extract had improved cognitive function and lower levels of Aβ oligomers and detergent-insoluble phosphorylated tau in the brain. These studies add to the body of evidence supporting the anti-neurodegenerative properties of *M. pruriens*.

3.6.2. Mucuna urens (L.) DC

Mucuna urens, commonly called horse-eye bean or ox-eye bean is a vigorous much-branched and twining climbing shrub with thick soft stems reaching tree canopies for better access to sunlight [244,245]. *M. urens* thrives well in both direct sunlight and light shade and gets along symbiotically with specific soil bacteria, which allows it to fix atmospheric nitrogen [227]. *M. urens* beans, like *M. pruriens*, have hairs that irritate the skin, causing intense pruritus, reddening, and the development of tiny pustules when in contact with the skin. The active agent responsible for the irritation is mucunain, which is a proteolytic enzyme [246]. The plant is found in the wild and used locally as medicine, a source of fibre and beads, and presumably as food [247,56]. The plant is used in several ways, for example, the powdered bean can be made into a tincture by macerating in alcohol and used as a soothing remedy against bleeding haemorrhoids [248]; the pods can be taken orally as an anthelmintic agent, though, the worms are expelled live [226]; the dried seeds are useful in producing flour used for food during drought, while the hairs from the seedpod are added to molasses syrup for expelling intestinal worms [249]; the cold water infusion of the leaves is used to treat abdominal discomfort while the root is prepared in honey for the treatment of cholera; the stems are cut and sap collected from the cut is used on sprains and sore muscles parts of the body with the rheumatic type of pains [227]; the fleshy stems have been used as a source of portable water in communities where such is lacking while the stems have fibres which are used for making ropes while beads and ornaments are produced from the seeds [250,251].

The seed extract in an *in vivo* study on male guinea pigs caused sperm degeneration and may thus be useful as a male antifertility agent [248]. Most parts of the plant contain physostigmine [57] and L-DOPA (levodopa), an amino acid found in the seeds, which encourages the brain's production of the neurotransmitter, dopamine [244]. Cooking, roasting and autoclaving affected the chemical constituents of *M. urens*. While autoclaving increased the nitrogen-free extract and resulted in lower levels of cystine, lysine, methionine, and other anti-nutritional factors like oxalate and phytate, cooked samples increased protein content from 24 to 27% and crude fibre from 3.5 to 4.5%. Furthermore, the levels of essential elements like zinc and copper increased using all the methods [252].

3.6.3. *Mucuna flagellipes hook. F*

Mucuna flagellipes, commonly known as cowitch (English) and *Ukpo* (southeastern, Nigeria), is an annual crop and can be cultivated for one year [253]. The hairy pod has been used in India for the treatment of snakebite while the stem is used for snakebite in West Africa [254]. Depending on the variety, the seeds are typically black or dark brown and occasionally speckled, while the leaves are trifoliate and greenish, with broadly ovate leaflets [255]. *M. flagellipes* leaves have a reduced energy value, a carbohydrate content of about 69.20%, crude protein content of less than 1.5%, fibre content of more than 10%, and ash content of 7.8%. Minerals including sodium, potassium, calcium, magnesium, iron, phosphorus, zinc, and iron have all been found to be present in varying concentrations in the leaves [256]. The high protein content of the seeds makes them compare favourably with animal proteins such as fish and beef. The cotyledons of the seeds are used as soup thickeners after cracking and boiling [257]. Typically, the antinutrients in the seed are affected by processing methods like soaking, boiling, autoclaving, and roasting. For instance, regardless of the amount of time spent roasting the seeds, phytate loss of more than 50% was observed and stachyose, raffinose, and tannin contents in the seeds were decreased by soaking and boiling [258].

The seeds of *M. flagellipes* were shown to be safe as the experimental animals used for the study had haematological and biochemical parameters within the normal range after administration. The leaf extract of *M. flagellipes* demonstrated inhibition of corrosion on mild steel in a sulphuric acid solution and the rate of corrosion was found to reduce with an increase in extract concentration [259]. *M. flagellipes* seeds have an appreciable amount of alkaloids, and a moderate quantity of phenols, tannins, steroids, terpenes, saponins and anthraquinones [58]. Two main compounds, hexadecanoic acid **(103)** and 9,12-octadecadienoic acid **(104)** have been isolated from the n-hexane fraction of *M. flagellipes* using GCMS analysis. The chemical structures of the isolated compounds are presented in Fig. 8. The n-hexane fractions also demonstrated anti-obesity and anti-hyperlipidemic activities in an animal model [260].

3.6.4. *Mucuna sloanei fawc. & rendle*

Mucuna sloanei, which is frequently grown in Nigeria, produces young fruits that can be cooked and consumed as vegetables and the ripe seeds are crushed and made into soups [261]. The seeds are popularly used as a thickener in soups and sauces after toasting and grinding [262]. The dehulled seeds are grounded and combined with palm oil for commercial use to create a yellow powder that is marketed as a soup thickener [261]. It is frequently used by the Igbos (eastern Nigeria) as a garnish or ingredient in the main course [262]. *M. sloanei* contains a black dye that is used throughout Nigeria to colour fibre and leatherbacks [59].

The entire parts of *M. sloanei* contain phytochemicals with significant medicinal benefits for both humans and animals. The plant also serves as a key raw material for Ayurvedic and traditional medicines. The seeds are high in carbohydrates, low in lipids (about 7%), high in protein (23–35%), high in fibre (9.6%), and satisfy the requirement for essential amino acids [263]. All of these factors contribute to the nutritional value of this underutilized legume. The most efficient methods for lowering the anti-nutrients in the seeds are hydrothermal treatments, fermentation, and germination [263]. Incorporating this low-cost legume will undoubtedly improve nutritional status and aid in the reduction of malnutrition [261]. Its fat content of about 7%, high fibre content, and high amount of polyunsaturated fatty acids increase its nutritional potential and the advantages associated with consumption. The nutritional value of *M. sloanei* seeds has been reported to be influenced by processing techniques. Iron, zinc, calcium, and phosphorus contents of *M. sloanei* were all increased by fermentation while calcium was decreased by cooking [261].

In addition to their typical medicinal benefits, *M. sloanei* seeds contain some antinutritional compounds that have a variety of health benefits. The phytic acid **(105)** isolated from *M. sloanei* has antioxidant, anti-carcinogenic, and hypoglycemic properties that are effective at low concentrations [263]. While tannins derived from the plants have also been reported to be 15–30 times more potent in quenching free radical activity than other simple phenolic agents, saponins from *M. sloanei* have been found to have hypocholesterolemic and anti-carcinogenic effects [263]. In addition, cooking and fermentation have been shown to cause a reduction in tannin and phytate contents *M. sloanei* [263].

3.7. *Indigofera L*

Indigofera is a genus of plants that includes herbs, shrubs, and small trees found in forests and savannas. According to IUCN, ninetythree species of the genus are underutilized, out of which 73 are in sub-Saharan Africa, fifty-five are endemic and some are already extinct. The genus has some species which produce indigo dye and are useful for crop shading, erosion control, soil protection and ornamental plants [70]. All parts of the plant are used as medicine for the treatment of skin diseases, swellings and wounds, digestive disorders and relief of pain [264]. *Indigofera* species have been used in several ways as decoctions for oral administration, and poultices for topical applications [264]. In Uganda and India, inhalation of the steam is common while in many countries they are used as an exclusive toothbrush for oral hygiene [264]. Crude extracts and purified fractions of *Indigofera* species have anti-arthritic [265], antidiabetic and antidyslipidaemic [264], anticonvulsant [266] anthelmintic [267] and anticancer properties [268].

3.7.1. Indigofera arrecta hochst. Ex A.Rich

Indigofera arrecta, popularly referred to as African indigo, is a member of the genus *Indigofera*, common in southwestern Nigeria, and also native to the east, central, south and other western parts of Africa. It is also found in the Phillippines, Laos and Vietnam [269]. It is a large, erect and woody shrub mainly found in uncultivated lands, forest borders and other open deciduous forest areas [270]. Indigo dye is primarily derived from the plant and the residue obtained after indigo extraction is used as compost [271]. *I. arrecta* is a soil improver and is therefore used as organic manure and a cover crop.

The plant is used in relieving ulcer pain, and other stomach ailments in many African communities. It also serves as a traditional cure for epilepsy, nervous syndrome and diabetes mellitus especially the dried leaves obtained from the young plant [60]. Its anti-bacterial activity and sore healing potential have also been reported [61]. The aqueous extract of *I. arrecta* lowered fasting plasma glucose levels in normoglycemic rats at specific concentrations; this effect was linked to non-glucose-induced insulin release from the pancreas [62]. The antidiarrheal potential of the aqueous and ethanol extracts of *I. arrecta* was evaluated on *Salmonella typhi, Escherichia coli and Shigella flexneri*. The results demonstrated that the ethanol extract was active at concentrations between 1 and 4.5 mg/mL, but its aqueous extract exhibited no activity [63]. The extract from the leaves of *I. arrecta* exhibited larvicidal activity against culex mosquito larvae as evidenced by the higher concentrations and high percentage mortality of culex mosquito larvae [64]. ***In vitro*** complement-modulating activity of *I. arrecta* showed that *I. arrecta* leaf extract inhibited the classical pathway only weakly (IC_{50} = 61.1 g/mL) and had no effect on the alternative pathway (IC_{50} = 585.0 g/mL) [272]. The antimicrobial properties of *I. arrecta* against common respiratory infection-causing organisms enable its traditional uses against tuberculosis, cough, and chest pain [65]. *Mycobacterium aurum* A+, *Staphylococcus aureus* and *Klebsiella pneumoniae* are all inhibited by the leaf extract [61].

The water and dichloromethane extracts of *I. arrecta* contain saponins, alkaloids, phenols, flavonoids, glycosides, anthocyanins, leucoanthocyans, and tannins. The leaf extracts specifically prevented the proliferation of cancer cells, and when combined with 5-fluorouracil, this antiproliferative activity was enhanced [273]. An *in vivo* study of the safety profile of the plant showed that the haematological indices were found to remain intact after administering up to 10 g/kg, p. o. for acute toxicity and 2 g/kg, p. o. for sub-chronic effect [274]. Additionally, these extract doses had no effect on the weights of the animals' kidneys, livers, or other organs, and none of the experimental animals used in the studies died or experienced any negative side effects like agitation or dyspnoea [274].

3.7.2. Indigofera tinctoria linn

Indigofera tinctoria also referred to as true indigo or "Néel," is widespread in Southeast Asia and tropical Africa. Depending on where the plant is, it can be annual, biannual or perennial with diverse uses in specified forms [66]. The roots and leaves have been used in hydrophobia and epileptic fits while the dry powder is used for asthma. In addition, in promoting hair growth, the roots as well as the stems and leaves are used [275]. The plant contains alkaloids, flavonoids, saponins, steroids, glycosides, phenolics, amino acids, carbohydrates, and tannins, as well as indirubin **(106)**, and indigtone, which are used in the treatment of hydrophobia [275]. *Indigofera tinctoria* is traditionally employed against kidney ailments [276]. The neuroprotective activity of the isolated compound from

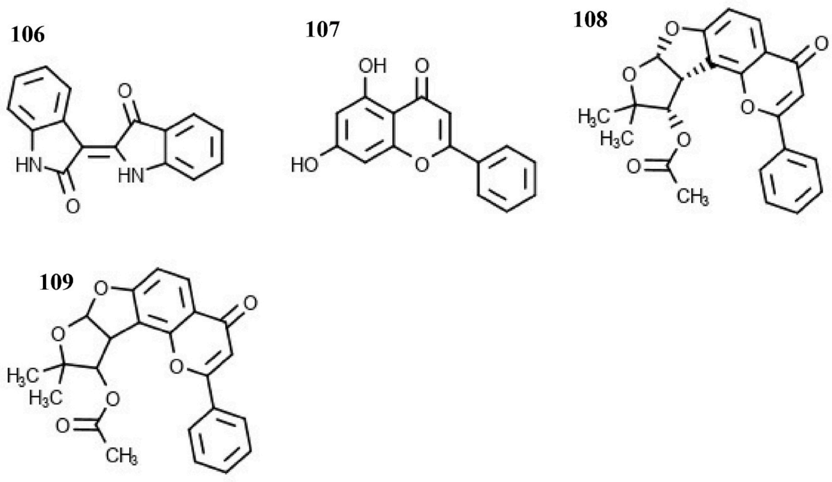

Fig. 9. Structures of some compounds isolated from the genus *Indigofera*.

the aerial parts of *I. Tinctoria* using *in vitro* and *in vivo* models of Parkinson's disease showed that a compound coded SF-6, offered a significantly higher ($p < 0.05$) inhibition of cytotoxicity and lowered free radical production. SF-6 demonstrated a dose-dependent radical scavenging activity. *In vivo* administration of SF-6 reduced contralateral rotational asymmetry significantly ($p < 0.001$) and prevented behavioural deficits in the experimental animals. These findings demonstrated neuroprotective activity that was more effective than that of the standard drug deprenyl, probably due to its antioxidant potential [277]. In rats with chronic noise stress-induced abnormalities, the immunoprotective and immunostimulating potentials of the leaves were demonstrated. The administration of 200 mg/kg (body weight) crude extract daily for two days stimulated both the innate and adaptive immune systems and restored normal levels of antibody secretion, phagocytosis, TNF-α expression, lymphocyte proliferation, and NK cell perforin expression in rats. The crude extract of the leaves significantly ($p < 0.05$) prevented immune system changes in rats exposed to noise [67]. At 100 mg/kg, the hydroethanolic extract of *I. tinctoria* leaves showed hepatoprotective properties against CCl4-induced hepatic injury in rats [278]. Chrysin **(107)**, a compound isolated from the leaves, inhibited A-431 cell proliferation significantly with an IC_{50} of 23.52 g/mL while causing no toxicity to normal HaCat cells [279]. *I. tinctoria* has been utilized in the preparation of Qing Dai, a Chinese medicine, which is frequently used to treat eczema, psoriasis, and inflammation [275]. In Burkina Faso and Sri Lanka, *Indigofera tinctoria* is used to treat diabetes [264]. Two compounds, pseudosemiglabrin **(108)** and semiglabrin **(109),** isolated from the ethanol extract of *I. tinctoria* at a ratio of 80:20 exhibited antidyslipidaemic activity (58). The chemical structures of the isolated compounds are presented in Fig. 9. From the results, hamsters given an oral dose of 50 mg/kg/day for seven days had increased levels of HDL cholesterol as well as reduced triglyceride levels, total cholesterol, glycerol, and free fatty acids when compared to the control. Other compounds from the aerial parts, such as gallatephrin and kaempferol-4',7-dirhamnoside, also displayed moderate and very low activity, respectively. Alloxan-induced diabetic rabbits were shown to respond favourably to oral doses of 150 and 200 mg/kg of the methanol extract of *I. tinctoria* leaves. The test groups in comparison to the negative control had significantly lower ($p < 0.01$) blood glucose levels [280].

3.7.3. Indigofera dendroides jacq

Indigofera dendroides is a small shrub that grows commonly in the West African region. The plant has extensive soil binding capacity, serves as one of the main dune stabilizers and is recognized as an ecosystem preserver. *I. dendroides* may thus be treated as the primary successor on dunes which is of economic and environmental importance [68].

The leaf juice is used in the treatment of severe inflammation, sores, and yawns in ethnomedicinal healing practices [69]. The leaf extract of *I. dendroides* demonstrated remarkable activity ($p < 0.05$) in all three mouse nociception models. One model (400 mg/kg), showed a greater effect than the standard drug, indomethacin. Extracts of the plant induce smooth muscle contractions that do not involve histaminergic receptors, calcium channels, and M1 muscarinic receptors, suggesting that acetylcholine assembles calcium from a tightly bound or intracellular pool, whereas high K+ and *I. dendroides* may mobilize calcium from the system's shallow or loosely bound pools [281].

3.7.4. Indigofera lupatana baker F

Indigofera lupatana, a woody shrub called 'Mugiti', is abundant in Kenya where it is commonly used to treat coughs and diarrhoea [282], gonorrhoea and pleurisy [283]**.** The different extracts of the plant contain phytosteroids, flavonoids, saponins cardiac glycosides as well as terpenoids. In addition, the plant has phenol, carboxyl groups, hydroxyl groups, ketones and aldehydes as identifiable functional groups. All the phytochemicals showed no oral toxicity on evaluation [284]. In folk medicine, *I. tinctoria* is commonly used to treat nervous disorders such as epilepsy [264]. The anti-epileptic property of the plant has been tested in rats using a lithium-pilocarpine model. The ethanol extracts of the plant administered orally demonstrated a significant ($p < 0.01$) reduction in the severity of status epilepticus comparable with diazepam [264]. The levels of brain monoamines have also been found to be significantly restored ($p < 0.01$) by the methanol extract of the leaves in maximal electroshock and pentylenetetrazole-induced seizure models in rats [264]. However, additional research needs to be conducted to clarify their mechanisms of action and isolate, identify, and standardize the plant's bioactive compounds.

3.8. Macrotyloma (Wight & Arn.) verdc

Macrotyloma, synonym *Kerstingiella* Harms., is a genus with 24 accepted species native to Africa, South West Arabian Peninsula, and the Indian Subcontinent. Macrotyloma is a pasture legume [285] that is used for fodder, green manure and as medicine and food for human consumption [71].

3.8.1. Macrotyloma geocarpum (harms) marechal and baudet

Macrotyloma geocarpum, with synonyms *Kerstingiella geocarpa* Harms., *Voandzeia geocarpa* (Harms) A. Chev., commonly known as Kersting's groundnut, ground bean, geocarpa groundnut, Hausa groundnut, *Doyiwé* (Benin), *La lentille de terre* (French), is an excellent source of protein, essential vitamins and minerals, though, it is an orphan legume crop that is largely under-researched and under-exploited [286]. It is native to Western Africa, specifically in Benin with a geographical spread in Cameroon, Central African Republic, India, Nigeria, Chad, Ghana, Senegal, and Togo [71]. The grains are high in protein, essential amino acids like arginine, phenylalanine, histidine, lysine, and methionine, and minerals like calcium, magnesium, zinc, iron, phosphorus, sodium, and potassium [286]. The presence of arginine, an essential amino acid responsible for growth in children makes it suitable for inclusion in infant food formulation where severe undernourishment is an issue [287]. The grains also contain vitamins like vitamins A, B1, B2 and B3, and are an excellent source of carbohydrates [288–291]. The seed has gained particular interest in the formulation of diets for people suffering from hypertension and those who seek weight loss due to its low fat and sodium contents. The seed is also beneficial for people with hypocholesterolemia and anaemia because of its low atherogenic index, which has the potential to reduce the incidence of atherosclerosis and coronary heart diseases [287]. The anti-nutritional constituents of the seeds, including tannin, hemagglutinins, and phytate, do not prevent consumption because they are almost completely removed by presoaking and boiling in water [287].

M. geocarpum is a versatile plant used for food, feed, and medicine [292]. The seeds are used in a variety of diets; they are boiled, seasoned with salt and vegetable oil, and consumed either singly or alongside other carbohydrates [293]. The flour from the seeds is used to make porridge, various local cakes (*Ata, Akara*), bean cakes (*Koose*), and boiled pastes (*Tubani*) [292]. As a weaning food for infants, a 70:30 mixture of flour and maize flour can be used because it has higher amino acid and mineral content than ordinary maize flour [286]. Due to its ability to absorb water and form an oil emulsion, the flour may be used in industries other than food as well as in the preparation of baked pastries and soups [294]. In Ghana, the seeds are boiled with baobab seeds for food while the young leaves are added to soups or served as vegetables. In dry seasons, the leaves and vines are harvested for use as animal feed, and the leaves are also for traditional medicine [290].

Traditionally, the water in which the seeds are boiled is consumed as a treatment for diarrhoea while the powdered seed and water or "pito", consumed as a local beer in Ghana is used as an emetic [292]. The plant is used to treat diabetes, fever, dysentery, and venereal diseases, and a vermifuge is made from the leaf decoction [295]. In Benin's traditional medicine, cultivars with black seed colour are used to treat diarrhoea, stomach upsets, and cough [287]. Despite the wide range of Kersting's groundnut in traditional medicine, little is documented about its bioactive compounds. Kersting's groundnut landraces differ in size, coat, colour, and texture, with the black, brown, and white seeds being the most noticeable [286]. The pigmentation of the seed coat is an appealing source of anthocyanin, antioxidants and natural food colourant [296]. Besides the role anthocyanins play in plants, they also have health benefits such as vision enhancement, and a lower risk of inflammatory, cardiovascular, and age-related degenerative diseases [286]. Kersting's groundnut with a black seed coat has been found to have the highest content of anthocyanins, total phenolic and flavonoid contents, as well as antioxidant capacity. The metabolomics analysis of Kersting's groundnut revealed 57 metabolites with phenolics, triterpenes, fatty acids, and sphingolipids being the most abundant [286]. The study revealed that the seeds are a potential source of nutraceuticals because of their ferulic acid, procyanidin B2, eryodictyiol-7-rutinoside, and quercetin pentoxide content [286].

3.8.2. Macrotyloma uniflorum (lam.) verdc

Macrotyloma uniflorum, popularly referred to as horse gram, is an underutilized legume indigenous to South Asian countries, Africa, Australia, and the West Indies. *M. uniflorum* is a protein-rich annual herbaceous crop that thrives in dry conditions (moderate rain) and moderately fertile soil. It is widely regarded as a poor man's crop [72]. Due to its high protein, vitamin, and mineral content, it can aid in the fight against protein malnutrition in developing nations. In India, horse gram is well known for its ethnomedicinal values. In times of drought and dry weather, it makes up a significant portion of the diet of rural residents. It is also a great source of dietary fibre, antioxidants, various micronutrients and bioactive compounds such as phytic acid **(105)**, a trypsin inhibitor [297].

The seeds of *M. uniflorum* are used to treat piles, hiccups, bronchial asthma, and abdominal lumps, and can also be used to regulate or stop excessive sweating [73]. The pharmacological properties of *M. uniflorum* include antihypercholesterolemic, antimicrobial, antiobesity, antihelminthic, analgesic, anti-inflammatory, anticholelithiasis, antioxidant, antiobesity, hepatoprotective, antidiabetic and antihypertensive [297]. Horse gram significantly reduces the fasting blood glucose levels as well as the serum triglycerides and total cholesterol levels in rats, suggesting its potential antidiabetic and antilipidemic agent [74]. The anti-inflammatory activity of horse gram aqueous extracts revealed that the extract inhibited snake venom phospholipase A2, VRV-PLA2, better than the other extracts used in the study. Separately, the aqueous extracts (100 μg) of the seed coat and pulp also inhibited VRV-PLA2 by 87.56% and 52.1%, respectively. The aqueous extract demonstrated comparable potency in preventing *in vivo* mouse paw oedema caused by PLA2 [298]. The chemical composition of the ethanol extract of M. uniflorum using GC-MS spectroscopy led to the identification of some phytoconstituents including ethyl alpha-d-glucopyranoside, n-hexadecanoic acid, linoleic acid (9, 12-octadecadienoic acid), stigmasterol and 3-beta-stigmast-5-en-3-ol. These studies revealed that horse gram is a highly nutritive and medicinal legume which should not be neglected due to its present consumption status but be projected as a major pulse.

4. Conclusion

Orphan legumes grow widely in many developing countries but their economic significance in global markets is limited. The analysis showed that some of these underutilized legumes possess great potentials to be used as food due to their superior dietary benefits and high protein content, which should not be neglected. The phytoconstituents and other anti-nutrient factors from these legumes exhibit varying degrees of pharmacological activities which could become important for the management of non-communicable diseases. Thus, some of the orphan legumes in the subfamily Faboideae should be projected as major legumes to tackle the present food insecurity while the phytoconstituents in some species could serve as a source of lead compounds for drug development for the treatment of diseases.

Author contribution statement

Omonike O. Ogbole, Queeneth A. Ogunniyi:Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Olufunke D. Akin-Ajani, Tolulope O. Ajala:Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Joerg Fettke:Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Oluwatoyin A. Odeku:Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Data availability statement

Data included in article/supplementary material/referenced in article.

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